Why research? We pursue research at Princeton to advance the understanding of our universe and our role in it, to increase fundamental human knowledge, and to serve the public welfare. These endeavors are critical at a time when the world faces daunting challenges of monumental proportions—the energy crisis, climate change, poverty, and infectious diseases, to name just a few—and when life as we know it is constantly altered by the inflow of new knowledge, and by the applications of this knowledge to technology and to culture.

Whether in molecular biology or sociology, theoretical physics or economics, computer science or chemical engineering, the advances enabled by research often have unexpected—indeed, unimaginable—future applications. A new molecule might one day become a new medicine or enable an alternative energy source. A new theory might transform the way we communicate with one another or comprehend the global economy. And the ability to glimpse, and ultimately manipulate, particles on the nanoscale might revolutionize the way we process information.

It would be impossible to overstate the importance of U.S. universities in driving the research engine of our nation and in training the next generation of leaders to thrive in an increasingly technological world. At Princeton, and at peer institutions across the nation, new knowledge is actively being created and applied in open, undirected environments that allow young minds to pursue their curiosity and stretch their imaginations, approaching old questions in novel ways, and answering new questions that have never been tackled. Supported by the University’s offices of corporate and foundation relations, technology licensing, the University’s offices of corporate and foundation relations, technology licensing, Princeton researchers are encouraged to share their expertise with industry and prepare intellectual property for commercial development. Using these avenues, the University is able to extend the value of its research and to benefit the public welfare. These endeavors are critical at a time when the world faces daunting challenges of monumental proportions—the energy crisis, climate change, poverty, and infectious diseases, to name just a few—and when life as we know it is constantly altered by the inflow of new knowledge, and by the applications of this knowledge to technology and to culture.
fundamental new knowledge can be translated into technologies and applications that improve lives around the globe.

These endeavors—knowledge creation and dissemination, the translation of basic research into applications, and perhaps most important of all, the education of young scientists and engineers—are integral to societal wellbeing, now and in the future. But success is not a foregone conclusion. Success will depend on a renewed and reinvigorated societal commitment to research and innovation. Success will depend on the widespread realization that scientific progress and innovation are not just important—they are critical—to the health of our economy and to global competitiveness. And success will depend on the willingness of national and global leaders to make the right choices, difficult though they may be, in selecting where and how and when to allocate limited resources in the face of intense pressure and competing demands.

For many decades the United States has enjoyed a special position as the world’s preeminent center of innovation, but America is now being seriously challenged by the forces of globalization and by increasing technological and industrial capabilities in Asia and Europe. At the same time, the recent economic downturn is forcing us to make difficult decisions about public and private U.S. investment in education, basic research, and innovation.

This situation has been worrisome for many years. In 2005, the National Academies’ Committee on Prospering in the Global Economy of the 21st Century issued a troubling report, “Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,” which showed that the scientific and technological building blocks critical to U.S. economic leadership were eroding just as many other countries were gaining strength, and warned that leadership, once lost, may not be possible to regain. Though the report received strong support over two presidential administrations and from congresses led by both parties, the storm clouds have not cleared. Instead, the committee felt compelled to issue a metaphorical alarm in a follow-up report in 2010 that the storm is now rapidly approaching a Category 5 hurricane, and “…we are now at a tipping point.”

Welcome to research at Princeton.

The hurdles we as a society find in front of us are massive, and we cannot be complacent. But we can be optimistic, provided that we make the right decisions going forward. The reason for hope is evident in the following pages, where you can read about the tremendous advances being made across the intellectual spectrum. Fueled by intellectual curiosity, a passion for educating, and a desire to serve national and international goals, Princeton scholars are expanding the knowledge frontier, inventing new technologies, and training and inspiring future generations of thinkers and leaders to find solutions to the problems that inevitably lie in the path ahead. Of course, one report cannot tell the whole story: the breakthroughs described here are but a snapshot of the University’s vibrant and thriving research enterprise.

A. J. Stewart Smith
Dean for Research and the Class of 1909
Professor of Physics
Princeton University
In departments, institutes, and centers across campus, University researchers are tackling some of the most pressing problems related to energy and the environment. The sheer size and scope of the challenges—from developing renewable energy sources to designing energy-conserving electronics to creating cleaner burning fuels—requires that numerous disciplines be deployed to address them. Accordingly, Princeton scholars have increasingly been forming interdisciplinary teams and multi-institutional partnerships to support their pathbreaking research efforts.

It is my hope that the diverse set of stories on the next few pages will give you a sense of the breadth and depth of Princeton’s recent research advances in this arena and also excite you about new centers and projects at the University that will enable future breakthroughs.

The energy and environmental hurdles we face are daunting, but I rest easier knowing that our researchers have fully embraced the challenge and are on the way to finding sustainable solutions for the future.

–Dean for Research A. J. Stewart Smith

Emily Carter, prominent scientist and engineer, selected to lead Andlinger Center

Emily Carter, a Princeton professor of engineering and applied mathematics, and eminent physical chemist, is serving as the founding director of the University’s Andlinger Center for Energy and the Environment.

“Emily Carter is just the right leader for the Andlinger Center as it steps up its activities and tackles some of the most urgent and complex problems of our time,” said President Shirley M. Tilghman. “She is a highly accomplished scientist who cares passionately about not only addressing the interlocking energy and environmental challenges that face us, but also training and inspiring the next generation of leaders in this field.”

The Andlinger Center was created in 2008 with the support of a $100 million gift from international business leader Gerhard Andlinger, a member of Princeton’s Class of 1952, and is currently based in the University’s Engineering Quadrangle. Princeton announced architectural plans in May 2010 for a major set of new buildings to house the center, whose mission is to build on Princeton’s strengths in environmental science, materials science, and policy to develop sustainable sources of energy that satisfy the world’s energy demand in a way that preserves natural resources and the health of the environment for future generations.

Carter came to Princeton in 2004 and has been a leader in developing and applying methods based on quantum mechanics to understand and design molecules and materials. In recent years she began focusing on applying her research tools toward improving energy technologies, including the harnessing of solar energy to generate electricity and produce fuels.
Carter, whose appointment was effective September 1, 2010, said her vision for the center is for it to become a vibrant intellectual community that engages people from many academic disciplines, as well as experts from industry and government.

“Any scientist or engineer who has the expertise to contribute to this field ought to be working on it,” said Carter. “The scale of the problem is immense. If you look at where we get most of our energy, 85 percent of it comes from non-renewable fossil fuels whose combustion products pollute our environment. If we want to reach the point of not using any fossil fuels at all someday, the problem is incredibly daunting.

“It’s going to take many different approaches and many people in different disciplines working in parallel and with a lot of cross-fertilization,” she said, noting she has cultivated this interdisciplinary approach to problem solving in her own research group, which consists of students from six different departments and programs at Princeton.

“I also want our work at the center to be done in tandem with economists and public policy experts who examine the technologies we’re working on and discuss with us how different solutions could fit into the marketplace and what sort of government policies are needed to allow these new technologies to take off and create new industries and jobs.”

Carter cited the University’s science departments as well as the Princeton Environmental Institute, the Princeton Institute for the Science and Technology of Materials, the Woodrow Wilson School of Public and International Affairs, and the School of Architecture as key partners. In addition, the federal labs on campus—the Princeton Plasma Physics Laboratory and the Geophysical Fluid Dynamics Laboratory—greatly augment the center’s mission, she said.

“With the intellectual firepower we have right now at Princeton and with the Andlinger Center now starting, we have the potential to make real progress on creating a clean energy future,” Carter said. “It is just a fantastic opportunity that Gerry Andlinger has provided, and I am honored to be part of it.”
Denise Mauzerall, an associate professor of civil and environmental engineering and public and international affairs, works with atmospheric chemistry models to estimate the flow and cumulative effects of air pollution, such as smog and soot from vehicles, to determine where regulators should focus their efforts.

Below: This map shows the source of black carbon deposits on glaciers in the southeast Tibetan Plateau (marked with a white square). Black carbon warms the atmosphere and increases melting rates when deposited on snow. By matching the colors on the image to the scale, researchers can determine the amount of black carbon from a particular region that traveled to the glaciers.

(Image courtesy of Denise Mauzerall/Monika Kopacz)

Mauzerall connects climate change, pollution in search for solutions

Aerosol particles, such as sulfate and black carbon emitted in China, have been found to have a far-reaching impact on human health as well as climate. A research team led by Denise Mauzerall, an associate professor of civil and environmental engineering and public and international affairs, in collaboration with the Geophysical Fluid Dynamics Laboratory (GFDL) at Princeton’s Forrestal Campus, found that although the vast majority of premature deaths from fine particles emitted in China occur within China, these particles also have an impact on health in countries as far away as Japan and the United States.

Both sulfate and black carbon increase rates of premature death, but sulfate cools the climate while black carbon warms it. Therefore, regulatory controls on specific future emissions from China will have a substantial impact on climate, Mauzerall said. Policymakers armed with this knowledge can potentially improve public health and reduce climate change simultaneously.

Mauzerall's research makes use of global chemical transport models to understand how pollutants from a particular location such as a city react in the atmosphere with other pollutants; how they move from the city to the suburbs across continents and oceans; and how they affect human health both near and far from their origin.

For example, because black carbon warms the atmosphere and darkens snow, it contributes significantly to the melting of Himalayan glaciers, which can lead to flooding in the short term and water shortages in the long term as the glaciers shrink. Mauzerall’s research group is using models to deduce the sources of black carbon arriving in the Himalayas, helping policymakers target potential emissions reductions in the source regions.

“We're able to see that although emissions from India and China are the largest sources of black carbon reaching the Himalayan glaciers, biomass burning in Africa affects the Himalayan glaciers, as well as pollution from Europe and the Middle East,” Mauzerall said.
Graduate student Ekua Bentil is using laser-based sensors to study how wood burning contributes to air pollution. Here, she visits a former slave castle in the town of Elmina, Ghana, where she is conducting her research.

In the researcher’s words:
Recent advances in the Combustion Energy Frontier Research Center

CHUNG K. LAW

Since the August 2009 establishment of the Combustion Energy Frontier Research Center (CEFRC), the center’s 15 principal investigators from seven academic institutions and two Department of Energy (DOE) laboratories have been pursuing the stated mission of “developing a validated, predictive, multi-scale, combustion modeling capability to optimize the design and operation of evolving fuels in advanced engines for transportation applications.”

Biobutanol and biodiesel have been targeted as the immediate fuels of investigation. In contrast to ethanol, which is the dominant biofuel presently marketed, biobutanol can be synthesized from various non-food sources, has higher energy content, mixes well with gasoline, is not corrosive, and is under active development by major energy and chemical industries for commercialization by 2013.

A major CEFRC advance has been the development of the first-generation reaction mechanism describing the oxidation of butanol, which is relevant for engine combustion. This significant advancement was achieved through the collaborative and coordinated efforts of all the CEFRC principal investigators, involving quantum mechanical computation of the reaction kinetics, diagnostics using laser and synchrotron radiation, flame propagation in high-pressure environments simulating the engine interior, and computational simulation of turbulent flames. A detailed understanding of this reaction mechanism is needed for the simulation and optimization of engine design and operation using biobutanol.

The center has also developed a strategy of blending ethanol and biodiesel in diesel fuel to moderate synergistically the undesirable soot emission propensity of diesel and the non-volatility of biodiesel. The concept capitalizes on the low-sooting property of biodiesel and the high volatility, or tendency to vaporize, of ethanol, which affects how readily the fuel can be burned. By tweaking the important fuel properties related to soot and volatility, this blending strategy and others like it hold promise for the design of future clean-burning and robust biofuels synthesized from a wide stream of biofeedstocks.

Bentil tracks poisonous gases with cutting-edge lasers

Electrical engineering graduate student Ekua Bentil received a fellowship from Princeton’s Center for Technology in Developing Regions to deploy a gas-sensing system in her native Ghana. Working with researchers at Ghana’s University of Cape Coast, Bentil will use the system to detect carbon dioxide, ozone, and water vapor in the air.

The ultimate goal of the project is to employ the sensor system to detect poisonous gases emitted from burning firewood. In Ghana, fish industry workers often preserve fish by drying it over wood fires in smokehouses, a practice that exposes them to noxious fumes.

In addition to the Ghana sensor project, Bentil is developing novel techniques to make lasers that emit only one wavelength of light at a time and can be “tuned” to different wavelengths. Since different gases absorb different wavelengths of light, a tunable laser could be used to detect the presence of numerous substances in the air or in human breath.

Both of her research efforts rely on the use of special lasers called quantum cascade lasers, which emit light in the mid-infrared region of the spectrum. Bentil’s adviser, electrical engineering professor Claire Gmachl, is the director of the National Science Foundation-funded Mid-Infrared Technologies for Health and the Environment (MIRTHE) Center on campus.

Graduate student Ekua Bentil is using laser-based sensors to study how wood burning contributes to air pollution. Here, she visits a former slave castle in the town of Elmina, Ghana, where she is conducting her research.

(Image courtesy of Ekua Bentil)
Problems in energy systems analysis require making decisions in the presence of different sources of uncertainty. On a finer time scale, we have to decide whether to use or store wind and solar energy, where to store it, and how to allocate energy resources in the presence of uncertainty in wind, weather, demand, and prices. On longer time scales, we need to make decisions about optimal investment decisions in the presence of uncertainty in rainfall and changes in energy supplies and prices, as well as changes in battery technologies, improvements in our ability to sequester carbon, the introduction of carbon pricing, and advances in our understanding of climate change.

We need models and algorithms that will solve these design and control problems, often because we need to understand how different components will interact, and how changes in technology and policy may affect the economics of different technologies. The fundamental equation guiding these algorithms is known as Bellman’s equation, but exact algorithms are limited in their capacity to solve massive and complex equations. In energy applications, we may face the need to solve time-dependent problems with hundreds of thousands of time periods and variables with tens of thousands of dimensions. In fact, it is not hard to create relatively small problems that would require centuries on a modern supercomputer to produce an exact solution.

We have developed a new class of algorithms based on approximate dynamic programming that combine tools from mathematical programming, machine learning, and simulation. These ideas were used in SMART, a stochastic, multi-scale model for the analysis of energy resources, technology, and policy. SMART is a multi-decade model for planning energy investments while capturing hourly variations in wind, solar output, demand, and prices. This model featured almost 200,000 time periods, which is well beyond the capabilities of commercial solvers running on supercomputers. By contrast, SMART produces high-quality solutions in a few hours running on a laptop.

In another study, the work of two undergraduates, Jessica Zhou ’10 and Ahsan Barkatullah ’12, was used to show that it is not enough to model the variability in the energy generated from wind; it is important to model the uncertainty in how much wind will be available. A new class of stochastic search algorithms, called the knowledge gradient, was used to produce near-optimal solutions for optimization models that control the use of generation plants in the presence of large supplies of energy from wind. This model showed that the error from ignoring uncertainty is substantial, and would distort studies that analyze the value of new storage technologies.
The idea of using plastics in lieu of metals in certain electronic devices is an attractive proposition—plastics are lightweight, easily processed, flexible, and often less expensive than their metallic counterparts—but efforts to do so have been hampered by difficulties in processing and molding plastics that conduct electricity.

A new method developed in the laboratory of Lynn Loo, an associate professor of chemical and biological engineering, enables the creation of contacts for transistors, or electronic switches, from polyaniline—a carbon-based conductive plastic. The low-cost technique uses a process similar to the one used to print newspapers to produce the transistors, which creates potential for scaling up the technique for mass production.

The conductivity and transparency of polyaniline make it a good candidate for replacing indium tin oxide, an expensive material currently used in solar cells and electronic displays. The demand for indium, a rare mined metal, has increased with the proliferation of electronic devices such as plasma televisions and smartphones, and its ongoing use at this growing rate is neither sustainable nor economically feasible. Commercially available solar panels created using a technique similar to the one developed in Loo’s lab could significantly lower the cost of solar cells, and therefore overcome some of the barriers to their more widespread use. Other potential applications include the creation of large-area displays, such as solar-powered display walls in bus stops, and low-cost disposable sensors for biomedical applications.

Princeton researchers have developed a new way to manufacture electronic devices made of plastic, employing a process that allows the materials to be formed into useful shapes while maintaining their ability to conduct electricity. In the plastic transistor pictured here, the plastic is molded into interdigitated electrodes (orange) allowing current flow to and from the active channel (green).

(Image courtesy of the Loo Research Group)
Carbon Mitigation Initiative receives $11 million through extended partnership with BP

In a continuing research partnership to identify ways to tackle the world’s climate problem, Princeton’s Carbon Mitigation Initiative (CMI) has received a commitment of $11 million from BP as part of an extension of their partnership first announced in October 2008.

BP and Princeton originally entered into a 10-year research agreement from 2000 to 2010, and CMI received $19 million from BP during this time to support the initiative’s research programs. CMI was created to investigate the climate and energy problem and has achieved recognition as both a successful interdisciplinary program at Princeton and an effective industry-university collaboration. It is part of the Princeton Environmental Institute (PEI), the University’s interdisciplinary center for environmental research, education, and outreach.

When the five-year extension of the joint partnership with BP was announced in 2008, the exact funding level had not been determined.

“The Carbon Mitigation Initiative at Princeton continues to advance our understanding of the scientific and policy issues associated with supplying the world’s increasing energy consumption while reducing carbon emissions,” said Lamar McKay, president and chief executive of BP America, who visited the Princeton campus in November 2010 to celebrate and reaffirm the renewal of the CMI partnership, which will run from 2011 to 2015. “We believe our partnership with CMI continues to yield answers to these complex questions, and for that reason we are delighted to extend our financial support for this effort.”

During the extension of CMI, scholars and students will explore further the science, policy, and technology dimensions of carbon mitigation.

Research focusing on the global carbon cycle will continue to narrow the uncertainty in the causes and magnitude of the drawdown of atmospheric carbon dioxide accounted for by the world’s forests and oceans. The research involves a combination of experimental and modeling investigations. The climate science group will further investigate the consequences of increasing ocean acidification for ocean plant and animal life, and the feedback loops on the carbon cycle that may result.

In addition, CMI’s carbon capture program will expand its analyses of systems for the capture of carbon dioxide at coal-plus-biomass synthetic fuels plants, with a new element of this program featuring thermochemical analysis.

Researchers in Morel’s group set up on-deck incubation tanks on a research vessel in the Gulf of Alaska to investigate the effect of ocean acidification on phytoplankton ecology. The project is part of the Carbon Mitigation Initiative’s effort to study the impacts of global change on the biosphere.

(Image by Dalin Shi)
Princeton researchers join nationwide project to boost energy efficiency of buildings

Princeton researchers are participating in a $122 million research project sponsored by the U.S. Department of Energy (DOE) to develop technologies and educational programs to make buildings more energy efficient.

As part of the project, scientists from Princeton's School of Engineering and Applied Science and the Princeton Plasma Physics Laboratory (PPPL) will receive a combined total of $4 million in funding from 2010 to 2015 to participate in a new national Energy Innovation Hub.

“This is an important and exciting collaboration between PPPL and the campus, taking advantage of their special expertise,” said Dean for Research A. J. Stewart Smith.

The project, led by Pennsylvania State University and based at the Philadelphia Navy Yard, brings together researchers from universities, national laboratories, and private industry to find ways to reduce energy use in buildings, which now accounts for 40 percent of U.S. energy consumption and carbon emissions. It is one of three energy innovation hubs that received funding from DOE in fiscal year 2010.

“The Energy Innovation Hubs are a key part of our effort to harness the power of American ingenuity to achieve transformative energy breakthroughs,” U.S. Secretary of Energy Steven Chu said in an announcement about the funding. “By bringing together some of our brightest minds, we can develop cutting-edge building energy-efficiency technologies that will reduce energy bills, cut carbon pollution, and create jobs.”

PPPL is focusing on education, with Science Education Program Head Andrew Zwicker leading one of the hub's central tasks—the creation of new education programs to train present and future workforces about energy-efficiency technology and systems, tailoring successful models developed at the laboratory for this new context.

Researchers from Princeton's engineering school are focusing on the development of sensors for measuring how energy flows through buildings, and on creating computerized systems that can use that information to better manage how homes are heated and cooled.

“Buildings account for 40 percent of this nation’s carbon footprint,” said David August, an associate professor of computer science.

“First we need to understand how buildings use energy. We plan to outfit existing buildings with enough sensors to account for every bit of energy flow.”

The researchers plan to focus on developing technologies that can be used in many different types of buildings. “We’re especially interested in finding ways to retrofit older buildings, because they represent a huge portion of the energy use in the United States,” said Naveen Verma, an assistant professor of electrical engineering.
Global collaborations: Enabling research, transforming results

Four thousand miles east of Princeton, not far from Geneva, Switzerland, University physicists are conducting research at the Large Hadron Collider (LHC)—the biggest and most powerful particle accelerator ever built that could enable unprecedented insights into the nature of matter.

Four thousand miles southeast of the LHC, in Kenya, Princeton scientists, engineers, architects, and social scientists at the Mpala Research Center and Conservancy are engaged in projects to promote sustainable human-wildlife coexistence and conserve biodiversity.

Some 7,000 miles west of Mpala, across the Atlantic in the Atacama Desert of northern Chile—the driest place on Earth—University astrophysicists are using the Atacama Cosmology Telescope to observe the birth and evolution of the universe.

The scientific approaches being brought to bear on these pressing problems and the goals of these three research efforts may differ significantly, but they have one crucial commonality: International collaboration is vital for success.

“The increasing strength and importance of international research collaborations is a natural result of the questions being asked in modern science,” said Dean for Research A. J. Stewart Smith. “We’re placing matter under more extreme conditions than ever before, we’re looking further into the universe than has ever been done, and we’re exploring biological systems in unprecedented levels of detail—no country has all the answers, all the experts or all the resources necessary.”

For a frame of reference, consider the Large Hadron Collider. Nearly 10,000 scientists from more than 100 countries are participating in the $10 billion project, which will hurl protons into one another at mind-boggling speeds for at least the next 20 years, generating unprecedented volumes of data that will take decades to analyze.

“It’s a tremendous opportunity for scientists, especially younger researchers, to gain extended exposure to countries other than the U.S., and also to participate in a project at this scale,” said Princeton physicist Daniel Marlow, an active LHC investigator. “The pure complexity of the project and the science requires amazing coordination and communication.”
Scientists participating in the project devote roughly half of their time to service, such as building and operating the machine, and half of their time to data analysis. For example, Princeton researchers are engaged in work to measure the luminosity of the accelerator—a basic measure of how well the accelerator is performing. Essentially, the more collisions, the higher the luminosity, and the better are their chances of detecting a very rare physics process. University physicists have responsibilities both for building the hardware that measures luminosity and for collecting luminosity data and ensuring its accuracy.

Like the LHC, many “big science” projects carry a price tag that all but requires collaboration among nations to foot the bill. But while monetary considerations do help drive the formation of international research partnerships, the need for such collaborations goes far beyond financial concerns. In this increasingly flat world, the world’s leading experts in a given field could be located anywhere. And when research programs aim to address problems or challenges specific to a particular region, it is absolutely imperative that local scholars play a vital role in the work.

“For real progress to occur, you can’t just go in, learn a lesson about a place, and go away,” said Kelly Caylor, a Princeton civil and environmental engineering professor, whose research at Mpala aims to understand interactions between patterns of vegetation and the water cycle.

Caylor is leading a research effort to understand how much water plants use by measuring how water returns to the atmosphere via two different processes that occur in the same place at the same time: evaporation from the soil and transpiration from plants, which occurs when water vapor is released from leaves.

While methods exist to measure how much water plants use on a very large scale, such as over North America, there are not currently any techniques for determining how water is used by plants on the scale of, say, a farmer growing corn in Kenya. Caylor’s research uses a state-of-the-art sensor to detect slight differences in the atomic composition of water vapor in the air depending on whether it comes from the soil or from plants.

Working with colleagues in botany and environmental engineering at Kenya’s Jomo Kenyatta University of Agriculture and Technology—the country’s leading agricultural and technical school—Caylor hopes his findings will inform the development of farming strategies that maximize the water available to plants to improve quality of life and reduce ecosystem degradation in the regions surrounding Mpala.

“There’s a need for a cultural dialogue, a need to think strategically, and a need to understand how things work in different countries—international collaborations are crucial for transforming research results into real-world solutions to real-world problems,” he said.

One way the University is cultivating ongoing, fruitful relationships with researchers around the world is through the establishment of the Global Collaborative Networks Fund, which supports the development of international scholarly networks that engage Princeton with centers of learning worldwide. The fund is administered by the Council for International Teaching and Research.

“Global Collaborative Research Networks are proposed by University faculty based on their areas of intellectual interest,” said Diana Davies, Princeton’s vice provost for international initiatives.
Our goal is to help build international communities of scholars rooted in long-term, personal connections, developed through collaborative work in any and all research areas. These communities will, in turn, be the foundation upon which Princeton can build multi-dimensional, sustainable relationships with the top universities and research centers around the world.”

The establishment of the research networks is among the initiatives that have been launched based on the recommendations of the President’s Advisory Committee on Internationalization, convened in 2006 by President Shirley M. Tilghman to consider how to “develop a set of strategic priorities and specific measures that will enable the University to fully realize [its] aspiration to be an American university with a broad international vision.”

The committee emphasized the need for Princeton international ventures to “enable and support faculty-driven activity,” observing that “research and exchanges work best at Princeton when the stakeholders are also the initiators and custodians of their efforts.”

The hope is that the new global networks will develop and prosper in a way similar to the partnership that has been established between Princeton and the National Institutes of Natural Sciences (NINS) of Japan, Davies said. For years, University scientists and Japanese scholars have been collaborating on fusion energy and astronomy projects. To date, these efforts have yielded numerous significant advances, including the 2009 discovery of a...
planet-like object made with the Subaru Telescope. Building on the success of existing partnerships, Princeton and NINS officially formalized their relationship in 2010 to support ongoing projects in the physical sciences and to launch a new effort in the biological sciences.

“As always, the University’s research agenda is driven by the intellectual interests of our faculty and a commitment to the creation, preservation, and transmission of new knowledge,” Smith said. “As research becomes increasingly interdisciplinary and complicated, international partnerships are crucial for finding answers to pressing societal challenges, maintaining Princeton’s status as a leading research university, and bolstering American competitiveness by ensuring that U.S. researchers play an important role in cutting-edge research efforts. And last, but certainly not least, the opportunity to engage in research projects with international partners—and often in international locales—provides critical educational opportunities and international experiences to Princeton students who will become the leaders of tomorrow’s ever more global world.”

A decade-long partnership between Princeton and the National Astronomical Observatory of Japan was launched in 2009 to search for planets, dark matter, and a deeper understanding of how galaxies are created using the Subaru Telescope, based on the dormant Mauna Kea volcano in Hawaii.

THE SEARCH FOR DARK MATTER AND A DEEPER UNDERSTANDING OF HOW GALAXIES ARE CREATED

New data from a Princeton-led team of geologists suggest that an episode called “snowball Earth,” which may have covered the continents and oceans in a thick sheet of ice, produced a dramatic change in the carbon cycle. This change in the carbon cycle, in turn, may have triggered future ice ages. The results, based on samples collected in Central and South Australia, were determined in collaboration with researchers at Northwestern University and Australia’s University of Adelaide.

GEOSCIENCES DISCOVERY: “SNOWBALL EARTH”

Research at the Mpala Research Center and Conservancy—in Kenya—co-directed by Princeton, the Smithsonian Institution, the Kenya Wildlife Service, the National Museums of Kenya, and the Mpala Wildlife Foundation—includes the Water, Savannas, and Society project. This research effort, part of Princeton’s Grand Challenges initiative, is determining the interconnections among water, vegetation, wildlife movements, and the activities of pastoral herders of central Kenya. The project aims to inform the development of more sustainable rangeland practices.

GRAND CHALLENGES: WATER, SAVANNAS, AND SOCIETY

International Research at Princeton University
Scientists identify perturbations in cancer pathways

A systematic listing of the ways a particular cancerous cell has “gone wrong” has been produced, according to results in *Molecular Cell*. The study addresses a fundamental challenge in cancer biology: understanding how perturbations to biological pathways and regulatory networks contribute to the development of cancer.

Led by Saeed Tavazoie, a professor in the Department of Molecular Biology and the Lewis-Sigler Institute for Integrative Genomics, researchers found they were able to systematically categorize and pinpoint the alterations in cancer pathways and to reveal the underlying regulatory code in DNA.

To do so, the researchers developed an algorithm, a problem-solving computer program that sorts through the behavior of each of 20,000 genes operating in a tumor cell. When genes are turned “on,” they activate or “express” proteins that serve as signals, creating different pathways of action. Cancer cells often act in aberrant ways, and the algorithm can detect these subtle changes and track all of them.

The algorithm devised by the group scans the DNA sequence of a given cell—its genome—and deciphers which sequences are controlling what pathways and whether any are acting differently from the norm. By deciphering the patterns, the scientists can conjure up the genetic regulatory code that is underlying a particular cancer.


Team finds breast cancer gene linked to disease spread

A long-sought gene that is fatefully switched on in 30 to 40 percent of all breast cancer patients, spreading the disease, resisting traditional chemotherapies and eventually leading to death, has been identified, according to results in *Cancer Cell*. Since the development of targeted cancer therapies requires an understanding of which genetic alterations induce disease, the findings may establish a new therapeutic target for breast cancer.

The gene, called “Metadherin” or MTDH, is located in a small region of human chromosome 8 and appears to be crucial to cancer’s spread or metastasis because it helps tumor cells stick tightly to blood vessels in distant organs. The gene also makes tumors more resistant to the powerful chemotherapeutic agents normally used to wipe out the deadly cells.

Led by molecular biologist Yibin Kang, scientists identified the gene using a computational biology approach. First, the team re-analyzed massive clinical breast cancer databases, revealing that study after study showed one area in common—a very small region in human chromosome 8 called 8q22. They found that this area of the chromosome is repeated many times in the genomes of poor-prognosis breast tumors.

Next, the team studied breast tumor samples collected from patients at the Cancer Institute of New Jersey, validating the computational prediction and confirming that the genetic sequence identified in the database was overproduced in the DNA of the poor-prognosis tumor samples. Among a handful of genes in the 8q22 region, MTDH was found to be responsible for the aggressive behavior of poor-prognosis tumors.

The scientists found that MTDH-overexpressing tumors are more likely to metastasize to the lungs, other vital organs, and bones. Importantly, these tumors were also found to be more resistant to a wide range of chemotherapeutic agents, including paclitaxel, cisplatin, and adriamycin. When researchers genetically altered the cancer cells to reduce the expression of MTDH, they became less able to metastasize and more likely to be eliminated by chemotherapy agents.

Biofilms—sticky aggregations of microorganisms—are the main form of microbial life and are usually considered to grow on wet surfaces ranging from riverbeds to sewer pipes to human teeth. There are few studies of how motion of the surrounding fluid affects biofilms, even though much of our living world involves flows, whether in rivers, our bodies, or human-made systems such as water purification plants.

In response to turbulence in fluid flows, biofilms have been observed to form string-like filaments called streamers, which are attached to a surface at one end while the other end floats freely in the surrounding fluid. These streamers are frequently found in rivers, hot springs, and acidic metal-rich waters, and they contribute to ecosystem processes as well as the fouling of membranes used for filtration and chemical processing, which reduces efficiency.

So, it came as a surprise to our group that when we performed very slow laminar flow experiments—in which there is no turbulence—with bacterial solutions in microfluidic channels containing corners, we systematically observed the development of streamers floating in the fluid. The streamers were found all along the length of the channel, rather than just being confined to the surfaces. Even more surprising, the streamers were attached only to the corners in the flow channel. Otherwise, they were floating freely in the fluid with the distinguishing feature that they were floating exactly in the middle of the channel.

Using a combination of approaches from fluid dynamics, engineering, and physics, we conducted systematic experiments, numerical simulations, and theoretical calculations of the fluid flow around corners. Our findings, based on work that began at Harvard University and continues at Princeton, hint at the manner in which the flow develops a regular three-dimensional pattern in the neighborhood of the corner, which may be the trigger for allowing the biofilm, initially on the surface, to develop as a thread in the flow.

Our findings suggest that streamers may be much more common than previously believed and that their presence can have a major impact on various flow processes, such as how biomass accumulates in filters. Our work emphasizes the need to not only examine the surface where a biofilm grows initially, but also to examine the immediate environment around the surface. We are now investigating several related problems for how fluid motion interacts with biofilm formation and function through collaborations with faculty members Bonnie Bassler, Zemer Gitai, and Ned Wingreen, so as to study problems at the interface of fluid dynamics and the molecular biology and structure of biofilms.


(Images by Roberto Rusconi)
In many areas of mathematics, the following equation plays an extremely important role:

\[ y^2 = x^3 + ax + b. \]

The graph of such an equation is called an “elliptic curve” (see Figure a, left). Number theorists are particularly interested in the case where \( a \) and \( b \) are whole numbers, like 0, 1, 2, 3, etc., or -1, -2, -3, etc. Moreover, they are especially interested in finding rational solutions to this equation, i.e., those rational values of \( x \) and \( y \) that make the equation true. (Rational numbers are numbers that can be expressed as ratios of whole numbers, e.g., 1/2, -3/4, 7/3 are rational numbers.) For example, \( y^2 = x^3 + 2x + 3 \) has the rational solution \( x = -1, y = 0 \), and also \( x = 3, y = 6 \), and also the less obvious rational solution \( x = 1/4, y = 15/8 \).

One reason elliptic curves are so structurally rich, and thus of particular interest to mathematicians, is that known solutions to their equations can be used to create new solutions by playing “connect-the-dots.” Here’s how it works: If you take any two rational points on an elliptic curve and draw a straight line between them, the line will always intersect the elliptic curve at a third rational point. Using this technique, you can start with some small set of rational points and use this procedure to find more and more (see Figures b and c, left).

According to Mordell’s Theorem—proven in 1922 by Louis Mordell—it is always possible to find some finite set of rational points on the curve, so that all of the rational points on the curve can be found from this finite set of points using the above connect-the-dots procedure. The minimal number of points needed to generate all the rational points on an elliptic curve is called the rank of the curve.

The question now arises as to whether the rank of the elliptic curve tends to increase, decrease, or stay the same as \( a \) and \( b \) get larger. In particular, does the rank approach infinity as \( a \) and \( b \) grow ever larger?

In our recent work, in collaboration with graduate student Arul Shankar, we have demonstrated that the rank, on average, actually has an upper limit as \( a \) and \( b \) tend to infinity. In fact, we find that the average rank of all elliptic curves is less than one. In particular, it follows that many—indeed, we show at least 10 percent—of all elliptic curves have no rational points!

Beyond advancing the subject of number theory in general, a heightened understanding of elliptic curves also has important implications in coding theory and cryptography. Encryption schemes, such as those used to protect our privacy when transmitting information online, often centrally involve the use of elliptic curves and the connect-the-dots construction.


**New technique reveals hidden images**

Researchers have developed a new technique for revealing images of hidden objects that relies on the ability to clarify an image using rays of light that would typically make the image unrecognizable, such as those scattered by clouds, human tissue, or murky water.

As described in *Nature Photonics*, the findings from the lab of electrical engineer Jason Fleischer represent a new way to create and exploit stochastic resonance—a phenomenon that occurs in certain “nonlinear” systems when energy from background noise actually amplifies a signal, rather than masking it. Their technique uses a “non-linear” crystal, which alters the behavior of light in non-standard ways, to mix signal and noise and tune the resulting output by stealing energy from the noise component to make the signal stronger.

Stochastic resonance has been observed in a variety of fields, including neuroscience and energy harvesting, but it has never been used in this way for imaging. Based on their results, the team also proposed a new theory for how noisy signals move through nonlinear materials, merging ideas from the fields of statistical physics, information theory, and optics.

New insights into histone code

A new method has been developed that dramatically improves the speed and accuracy of measuring a special class of proteins called histones, which are at the core of every chromosome and control the way instructions in DNA are carried out. The technique offers a long-sought tool for studying stem cells, cancer, and other topics of fundamental importance to biology and medicine.

Despite rapid progress in understanding the information encoded in DNA and genes, scientists have achieved much less insight into the so-called “histone code,” which determines why a gene in one cell functions differently from the same gene in another cell. Distinguishing between various modified forms of a histone has been challenging because several combinations of different modifications can have nearly the same mass.

Indeed, under conventional tests, two histones with very different functions could appear identical if they have the same set of modifications but are at different locations on the molecule. The new technique, reported in *Molecular and Cellular Proteomics*, reduces by a factor of 100 the time it takes to analyze histones and also requires less sample material than existing methods. The process uses a combination of physical, chemical, and mathematical techniques to separate histone variations from one another and break them into small fragments, at which point differences in the locations of modifications become more apparent. These small fragments are then repeatedly compared until a highly accurate list of histone modifications and their locations has been produced.

The research team was led by molecular biologist Benjamin Garcia and chemical and biological engineer Christodoulos Floudas.


‘Civic technologies’ provide access to government records and publications

Two Web-based technologies were launched in 2009 to illuminate the workings of government by making court records and the federal government’s “newspaper,” the Federal Register, easily accessible online.

One of the technologies, dubbed RECAP, is an extension for the Firefox Web browser that gives users free access to records from PACER, the pay-per-page system for accessing records of the U.S. Federal District and Bankruptcy Courts. PACER stands for Public Access to Court Electronic Records; RECAP is PACER spelled backward.

The other, FedThread, is a website that helps people parse the Federal Register, a daily publication of the federal government that provides highly detailed coverage of important rules, proposals, and actions taken by the government.

The technologies were developed by computer scientists Edward Felten and Stephen Schultzze, the then-director and associate director, respectively, of the Center for Information Technology Policy. Felten is currently serving a one-year term as the U.S. Federal Trade Commission’s first chief technologist.
3-D computer simulations help envision supernovae explosions

A team headed by astrophysicist Adam Burrows has found a way to make computer simulations of supernovae exploding in three dimensions, as described in The Astrophysical Journal.

Even though these mammoth explosions have been observed for thousands of years, for the past 50 years researchers have struggled to mimic the step-by-step destructive action on computers. Such simulations are important, as they can lead to new information about the universe and help address longstanding problems in astrophysics.

In the past, simulated explosions represented in one and two dimensions often stalled, leading scientists to conclude that their understanding of the physics was incorrect or incomplete. This team used the same guiding physics principles, but used supercomputers that were many times more powerful, employing a representation in three dimensions that allowed the various multidimensional instabilities to be expressed.

The new 3-D simulations are based on the idea that the collapsing star itself is not sphere-like, but distinctly asymmetrical and affected by a host of instabilities in the volatile mix surrounding its core. The scientific visualization employed by the research team is an interdisciplinary effort combining astrophysics, applied mathematics, and computer science. The endeavor produces a presentation through computer-generated images of three-dimensional phenomena.

To do their work, Burrows and his colleagues came up with mathematical values representing the energetic behaviors of stars by using mathematical representations of fluids in motion—the same partial differential equations solved by geophysicists for climate modeling and weather forecasting. To solve these complex equations and simulate what happens inside a dying star, the team used an advanced computer code called CASTRO that took into account factors that changed over time, including fluid density, temperature, pressure, gravitational acceleration, and velocity.

Disrupting bacterial small talk could limit disease and lead to new antibiotics

In quorum sensing, the process of cell-to-cell communication in bacteria, infectious cells wait until their numbers have increased to a certain threshold and then launch a coordinated attack on their host. Interfering with that communication could be the key to preventing a deadly assault, according to a study published in Molecular Cell.

The finding by a research team led by molecular biologist Bonnie Bassler, who has worked on quorum sensing since 1990, indicates that a new kind of antibiotic targeting these mechanisms might be effective and feasible.

The researchers disrupted the bacterial small talk by developing inhibitors that jammed receptors for bacterial communication molecules called acylhomoserine lactone autoinducers. These autoinducers drive quorum sensing among Gram-negative bacteria such as Salmonella and E. coli.

The team developed inhibitors that jammed two types of receptors in Gram-negative bacteria that detect the communication molecules and trigger changes in the activity of virulence genes. One receptor type, LuxR, connects with a partner autoinducer inside the cell. Another type of receptor, LuxN, binds its corresponding molecule outside the cell.

The researchers tweaked a molecule that they had previously identified in a drug screen for compounds that inhibit quorum sensing to develop two strong inhibitors called chlorothio-lactone and chlorolactone. One of them, chlorolactone, worked so effectively that it protected a model roundworm, Caenorhabditis elegans, from dying due to an infection by a bacterial pathogen, according to the researchers.

These results suggest that interfering with quorum sensing could provide a new way to develop nontraditional antibiotics. Conventional antibiotics often foster resistance by killing off drug-susceptible bacteria, but allowing resistant strains to survive and reproduce. By attacking bacteria in a different way, this new approach may reduce this dangerous problem, which can create “superbugs” that are nearly impossible to treat.

Housing externalities refer to the effect that the characteristics of a house have on the value of nearby homes. They are pervasive in residential neighborhoods. As most people know, investments in one neighbor’s house affect the beauty, cleanliness, and overall amenities of a block and, as a result, affect the value of other houses in the area. Therefore, the magnitude and spatial scope of these externalities is a key determinant of the social return to urban revitalization policies, like local investment subsidies or affordable housing projects, as well as events that lead to vacant housing units, like the massive foreclosure wave experienced in U.S. cities in 2007–10.

Measuring housing externalities is a complicated task because of a standard reverse-causality problem: The value of a house may be high because it is surrounded by high-value houses, but the house may be surrounded by nice houses because its value is high. So to measure these externalities, we need to investigate changes in the value of houses that are caused by external factors and unrelated to the current values of the homes.

In our research published in the *Journal of Political Economy*, we considered an urban revitalization program implemented in Richmond, Virginia, which subsidized housing investments in poor neighborhoods. Using this program and individual housing transactions data, we measured that housing externalities in these neighborhoods were largest in the areas closest to the homes receiving subsidies, and that these effects declined with increasing distance from the targeted homes. For example, land price increases next to the houses receiving subsidies were about 10 percentage points higher than in similar areas that did not receive the subsidy. Further away—at a distance of 2,000 feet from targeted homes—land prices were only about 2.5 percentage points higher than in comparable areas that were not part of the revitalization program. The final outcome was that each dollar invested in the program raised total land values in a 3,000-feet radius by about six dollars in a six-year period.

The magnitude and scope of the measured housing externalities indicates that the social value of this policy was positive and large. It also suggests that the current wave of foreclosures is probably reducing the value of urban land in the U.S. way beyond its direct effect on foreclosed homes because of the negative housing externalities generated by vacant homes.


**Facial characteristics, expressions drive split-second judgments**

A computer program developed by scientists allows them to analyze better than ever before what it is about certain human faces that makes them look either trustworthy or fearsome. The program also allows researchers to construct computer-generated faces that display the most trustworthy or dominant faces possible.

As described in the *Proceedings of the National Academy of Sciences*, the work could have implications for those who care what effect their faces may have upon a beholder, from salespeople to criminal defendants. Conducted by psychology and public affairs professor Alexander Todorov and research specialist Nikolaas Oosterhof, the research extends an ongoing inquiry into the myriad messages conveyed by the human face.

Taking what they have learned over time—namely that, rightly or wrongly, people make instant judgments about faces that guide them in how they feel about that person—the researchers sought a way to quantify and define exactly what it is about each person’s face that conveys a sense they can be trusted or feared.

Based on their data, the scientists found that humans make split-second judgments on faces on two major measures—whether the person should be approached or avoided and whether the person is weak or strong.
Wild Scottish sheep could help explain differences in immunity

Strong immunity may play a key role in determining long life, but may do so at the expense of reduced fertility. An 11-year study of a population of wild sheep located on a remote island off the coast of Scotland that gauged the animals’ susceptibility to infection may give new insight into why some people get sicker than others when exposed to the same illness.

The answer to this medical puzzle may lie in deep-rooted differences in how animals survive and reproduce in the wild, according to a study led by ecologist Andrea Graham. The research, published in *Science*, revealed that the sheep population over time has maintained a balance of those with weaker and stronger levels of immunity and fertility.

Graham, who also is on the faculty of the University of Edinburgh, led the study of wild Soay sheep on the remote island of Hirta in the St. Kilda archipelago, about 100 miles west of the Scottish mainland. The scientists tested the animals for levels of antibodies, natural molecules produced by the sheep’s immune systems to fend off infections such as influenza or those caused by parasitic worms.

The sheep whose blood contained the most antibodies lived the longest, the researchers found. These animals also were most likely to survive harsh winters. However, they failed to produce as many offspring each spring as other sheep. Sheep with lower levels of antibodies tended to die earlier, they found, but also gave birth to more lambs each year.

Viewed in terms of breeding and, ultimately, evolutionary success, the differing groups of sheep were equally successful in that the longer-lived but less fertile sheep and the shorter-lived but more fertile sheep produced about the same number of progeny over the course of their lives.

The overall balance could help explain why immunity varies so much among individuals.


The psychologists also used a commercial software program that generates composites of human faces (based on laser scans of real subjects) to explore how test subjects rated 300 faces for trustworthiness, dominance, and threat. Common features of both trustworthiness and dominance emerged. A trustworthy face, at its most extreme, has a U-shaped mouth and eyes that form an almost surprised look. An untrustworthy face, at its most extreme, is an angry one with the edges of the mouth curled down and eyebrows pointing down at the center. The least dominant face possible is one resembling a baby’s with a larger distance between the eyes and the eyebrows than other faces. A threatening face can be obtained by averaging an untrustworthy and a dominant face.

While it may be true that people have little control over their facial features, the study indicated that expressions may be important to others’ perceptions as well, which could have implications for people in jobs that require extensive interactions with the public.

Real-world scenes, such as cityscapes or mountain vistas, are cluttered and contain many different objects. The capacity of the visual system to process the information that is present in these scenes is rather limited, so the brain has developed neural mechanisms to select the information that is most relevant for guiding current behavior.

Traditionally, the problem of attentional selection from natural scenes has been studied in laboratory settings, where the clutter of a scene is mimicked by visual displays containing a large number of more simple objects, such as shapes or letters. While this approach helps to control many physical parameters of the stimuli present in a visual display, such reductionism may barely reflect the true complexity of natural vision as a result. In an attempt to understand attentional selection from ecologically more relevant visual displays, we have begun to investigate the neural mechanisms underlying natural scene categorization in the human visual system using functional brain imaging with an MRI scanner.

In daily life, we often extract visual object information at the categorical level from our environment. For example, when we cross the street, we look for cars as a general category, and not necessarily for a specific exemplar that belongs to that category. In a study reported in *Nature*, we asked our subjects to detect either people or cars in more than 2,000 outdoor scenes that were briefly presented while our subjects underwent brain imaging.

We found that the neural activity in the object-selective cortex—a brain region that responds more strongly to objects than to other visual stimuli—that was evoked by the scenes depended entirely on the subject’s task: It reflected information about the category “people” when subjects performed the people detection task, but not when subjects performed the car detection task, and vice versa. These results suggest that looking for a particular piece of information in a scene renders us “blind” to other information that is present but not relevant to behavior. Our findings imply that neural activity in sensory processing areas is primarily determined by internally generated signals related to ongoing behavior, rather than by the physical properties of the visual world.

Scientists find an equation for materials innovation

Researchers have developed a new model for predicting the kinetic energy of electrons in semiconductors from only the electron density. An understanding of electron kinetic energy can be used to help determine the structure and other properties of a material, such as how it changes shape in response to physical stress, thereby allowing researchers to simulate and predict important characteristics of a new material before it has been created.

The new theory, reported in Physical Review B, traces its lineage to the Thomas-Fermi equation, which relates the kinetic energy of electrons to how the electrons are distributed in a material. Understanding this relationship is important because the distribution of electrons is easier to measure than the energy, but knowing the energy of electrons is more useful than the distribution for designing materials. The Thomas-Fermi equation was based on a theoretical gas, however, and for decades scientists have sought a working equation that could be applied to real materials.

In the absence of a solution, researchers have been calculating the energy of each atom from scratch to determine the properties of a substance. The laborious method bogs down the most powerful computers if more than a few hundred atoms are being considered, severely limiting the amount of a material and type of phenomena that can be studied.

Emily Carter, a professor of engineering and applied mathematics, led the team that developed the new model. The research addressed a disparity observed in her earlier work when an accurate working model that was developed for predicting the kinetic energy of electrons in simple metals failed to make accurate predictions for semiconductors. By modifying the model to account for the fact that metals and semiconductors respond differently to electrical fields, the team developed a model that worked for a wide range of materials, extending the range of elements and quantities of material that can be accurately simulated.


Study finds racial dimensions to foreclosure crisis

The predatory targeting of minorities in segregated urban areas was a key factor in the recent U.S. mortgage foreclosure crisis, according to new results published in the American Sociological Review.

Although the rise in subprime lending and the ensuing wave of foreclosures was partly a result of market forces that have been well documented, the foreclosure crisis also was a highly racialized process. Graduate student Jacob Rugh and sociologist and public affairs professor Douglas Massey found that pervasive residential segregation created a niche of minority clients who were marketed risky subprime loans.

Such loans were in great demand for use in mortgage-backed securities that could be sold on secondary markets.

Rugh and Massey used data from the 100 largest U.S. metropolitan areas to test their argument. Findings showed that black segregation and, to a lesser extent, Hispanic segregation were powerful predictors of the number and rate of foreclosures in the United States—even after removing the effects of a variety of other market conditions such as average creditworthiness, the degree of zoning regulation, the overall rate of subprime lending, and coverage under the Community Reinvestment Act, a 1977 law that sought to reduce discriminatory credit practices in low-income neighborhoods.

A special statistical analysis provided strong evidence that the effect of black segregation on foreclosures was causal and not simply a correlation.

Online survey system sifts through ideas

Researchers have developed a new way for organizations to solicit ideas from large groups of people and simultaneously have those same people vote on the merit of the ideas generated by the group. Called “All Our Ideas,” the survey tool melds concepts from sociology and computer science to allow an organization to quickly set up a free website where large numbers of people can contribute and rank ideas.

Created by sociologist Matthew Salganik in collaboration with computer scientists, All Our Ideas allows survey makers to present respondents with a question and let them choose which of two answers they find more appropriate. If none of the answers seems ideal, the user can submit a new idea, which will join the pool of answers that are voted on in pairs.

Although other surveying applications exist, All Our Ideas is designed to avoid pitfalls that have plagued some online systems. For instance, to address the issue of people gaming the system by voting on their favorite entry multiple times, the system randomly selects the two voting choices presented to respondents, making it more difficult for someone to repeatedly find and vote for a specific entry. Site visitors also make their choices blindly, without having seen the rank- ings of the various ideas, which prevents them from being biased by other people’s opinions. Additionally, the system accounts for some ideas being in the system longer than others, preventing older entries from dominating the rankings because they’ve been voted on more times.

Financial instruments could be spiked with unfindable risks

In a result that may have implications for financial regulation, computer scientists and economists have revealed potentially impenetrable problems with the pricing of financial derivatives. They show that sellers of these investments could purposefully include pieces of bad risk that no buyer could detect even with the most powerful computers.

It is now standard wisdom that a major culprit in the 2008 financial meltdown was use of simplistic mathematical models of risk at financial firms. The new findings, published in Innovations in Computer Science, suggest that the problems may go deeper. The research team included computer science professors Sanjeev Arora and Boaz Barak, economics professor Markus Brunnermeier, and computer science graduate student Rong Ge.

The research focused on collateralized debt obligations, or CDOs, an investment tool that combines many mortgages with the promise of spreading out and lowering the risk of default. The team examined what would happen if a seller knew that some mortgages were “lemons” and structured a package of CDOs to benefit himself. They found that the manipulation may be impossible for buyers to detect either at time of sale or later when the derivative loses money.


Rong Ge, a graduate student in computer science, was part of a team that applied a computer science theory known as intractability to study the pricing of financial derivatives.
Chemical competition: Research identifies new mechanism regulating embryonic development

Protein competition over an important enzyme may provide a mechanism to integrate different signals that direct early embryonic development. Research published in *Current Biology* suggests that these signals are combined long before they interact with the organism's DNA, as was previously believed.

The fought-over enzyme, known as the mitogen-activated protein kinase (MAPK), is found in all complex organisms, ranging from yeast to humans. MAPK signaling pathways, or chemical networks that involve the enzyme, are critical for normal development, and defects in these pathways can lead to severe developmental disorders and cancer.

During early embryonic development, a single undifferentiated cell becomes a complex and highly specialized organism containing a variety of different cell types arranged in very precise patterns. These patterns, which ensure that the body structures from head-to-tail and front-to-back develop correctly and in the appropriate places, are created when cells respond to a series of chemical signals from different signaling pathways. The different patterning signals received by any given cell are ultimately combined to govern its future fate and tell it what kind of cell it should become.

Conventional biology teaches that enzymes like MAPK act on certain molecules, called substrates, to regulate chemical reactions. The new findings, based on work in the lab of chemical engineer Stanislav Shvartsman, are surprising because it appears that, through competition with one another, the substrates of MAPK are, in fact, influencing the enzyme’s activity.

A team led by chemical engineer Stanislav Shvartsman found that protein competition over an important enzyme may provide a mechanism to integrate different signals that direct early embryonic development. The team used confocal microscopy to visualize the spatial distribution of two proteins that compete for an important enzyme, called MAPK, in early fruit fly embryos. In areas where levels of a protein important for the development of the head were high (shown here in red, with brighter color indicating the presence of more protein) there was less enzyme available to act upon a different protein (shown here in green) that is important for the development of the ends of the embryo, including the tail.

(Images courtesy of the Shvartsman lab)
The opening of Frick Chemistry Laboratory—the new home of the University's Department of Chemistry—presents the perfect staging area to break scientific ground, to engage students by actively involving them in cutting-edge work, and—according to the department’s leader—to provide “the best education in undergraduate chemistry in the world.”

“What we want is for Princeton to be the best place to conduct chemical research and to learn chemistry on a global level,” said David MacMillan, the chair of the department, who is overseeing a bold expansion with recruitment of top-tier faculty. “We are going to get there by doing what Princeton does best, which is to focus on the best people, from professors at the height of their careers to undergraduate students taking their first major steps toward realizing their potential.”

Of prime importance, the department aims to recruit talented graduate students and nurture their development into the best researchers in the world in the chemical sciences, added MacMillan, the A. Barton Hepburn Professor of Organic Chemistry.

“That’s the plan, and we are not going to deviate from it,” he said. “The building being probably the best chemistry building on the planet for academia is in alignment with that.”

Featuring two wings and a central atrium, the modern building was designed to foster cross-disciplinary collaboration.
Key research areas

“We will be focusing on areas where chemistry mixes directly and significantly with other leading disciplines, such as biology, physics, and engineering, and, notably, where they are expected to produce solutions with a pronounced, beneficial impact on society,” MacMillan said.

“These four areas represent the bulk of what chemists will be researching over the next 20 years,” MacMillan said.

- **Chemical biology:** Scientists will cross disciplines to engage in projects that intersect with many subjects in biology, such as biophysics and bioinorganic chemistry. The goal is to create or aid in the development of new medicines through a better understanding of biology at the chemical or molecular level.

- **Energy:** This research will seek to expand the capability of alternative energies, such as designing chemical capacitors to store photonic energy from sunlight, using hydrogen and oxygen bonds.

- **Materials:** Collaborations will include quests for new materials with the ability to convey electrons and photons at higher speeds and capacities that will intensify as the demand for faster computers and high-quality imaging systems grows.

- **Catalysis and chemical synthesis:** Catalysis, the speeding up or sometimes the slowing down of the rate of a chemical reaction, is caused by the addition of some substance that does not undergo a permanent chemical change. The search for new catalysts is of wide interest in both research and industry. Researchers will undertake plans to find new catalysts to develop new chemical reactions that will reshape the way scientists think about the construction of complex molecules—a central requirement for the discovery of new medicines.

Facilities aid in recruiting, enable cutting-edge research

When building the Frick Chemistry Laboratory, many of the chemistry department’s researchers had an opportunity to consult with designers and architects to ensure that the space would meet their needs in terms of accommodating workspace and scientific instrumentation. The building was a crucial aid in recruiting new faculty, MacMillan said. “There is no doubt that scientists were attracted to the new building with its state-of-the-art labs and instrumentation and the opportunities it offered for enhanced collaboration, both within the department and outside it.”

Left: Using the OrgCAST technology for accelerating drug discovery, researchers in the lab of David MacMillan, the A. Barton Hepburn Professor of Organic Chemistry, were able to produce 4 million drug-like molecules—a massive and diverse collection that previously would have taken decades to amass.

Right: The HepatoChem process developed in the lab of John Groves, the Hugh Scott Taylor Chair of Chemistry, mimics the function of the liver to enable thorough biochemical analysis of drug compounds at many times the speed of standard techniques.
Building’s equipment serves research and industry

Frick Chemistry Laboratory’s 265,000-square-foot of space houses facilities for nuclear magnetic resonance imaging, mass spectroscopy, catalysis, and biochemical separations.

While some of the instruments in the Frick Chemistry Laboratory are dedicated to particular faculty-led research groups, the building contains four shared facilities. Most are located in the basement because of research functions that require very low vibration conditions, but the feeling of open collaboration is maintained, as the facilities are visible behind glass walls. The facilities are critical to the research work of undergraduates, graduate students, and post-doctoral fellows, all of whom have equal access to the technology.

A collection of seven nuclear magnetic resonance (NMR) machines serves the campus and is used by many academic collaborators. The NMR facility is designed with support areas such as the data-handling room, a sample preparation room with a sterile hood, and a meeting room for educational activities and for use by senior thesis students. The instruments are largely hands-on and can be operated by students and postdoctoral researchers for their own experiments, although lab directors will be available for consultation and collaboration on more sophisticated applications.

The building also houses a new mass spectrometry facility that accommodates several machines acquired in recent years in a spacious, open setting. Mass spectrometry is a highly sensitive technique that identifies chemicals based on their size and electrical charge.

Most of the spectrometers at Frick Chemistry Laboratory are available to experimenters on campus. The design of the mass spectrometry facility allows for the incorporation of new instruments without serious disruption. The director of the spectrometry facility trains and supervises students to use the facility, and also carries out collaborative experiments.

The Merck Catalysis Center and a “separations facility” maintained by the department share another all-glass enclosure. The catalysis center, the result of collaborative funding from Merck & Co. and the University, is open for research to all faculty.
While the catalysis center focuses on the development of new catalysts through efficient screening technology with automated analysis and robotic operation, the biochemical separations facility makes available technology and expertise for purification of organic compounds, with a focus on chiral separations using liquid carbon dioxide as a solvent. The director of the facility and two staff members carry out purifications primarily for the chemistry and molecular biology departments, as well as for outside users from industry.

According to MacMillan, it is all in keeping with what the University needs in order to lead the field.

“If you want to have quality, there has to be quality in every component,” he said. “So you need the best people, the best students, you have to have the best infrastructure, the best building, the best staff—every component of it has to be of such high quality.”

“The University values deep scholarship and at the same time supports innovative, groundbreaking ideas…. It is absolutely exciting to be part of the team that continues to create new opportunities to advance Princeton chemistry, with a pace that accelerates exponentially with every addition of a new member.”

—Associate Professor of Chemistry Haw Yang, who joined the faculty in 2009. Yang’s research is at the forefront of physical chemistry, materials chemistry, and the biophysics of single biological macromolecules.

“‘It’s motivating to be a part of this—I can look down the long hallway and see many of my colleagues…. My students are constantly bumping into students from different research groups, and their exchange of ideas is good for our science…. It is not insular here.”

—Assistant Professor of Chemistry Abigail Doyle, who joined the faculty in 2008. Doyle’s research focuses on the design of new and efficient ways to synthesize biologically active molecules and chemical tracers for positron emission tomography imaging studies.

“It’s important to have bridges between disciplines.”

—Thomas Muir, the Van Zandt Williams Jr. Class of 1965 Professor of Chemistry, who joined the faculty in 2011. One of the world’s premier chemical biologists, Muir’s research combines tools of organic chemistry, biochemistry, and cell biology in efforts to develop a suite of new technologies that provide fundamental insight into how proteins work.
Stewart Prager, the director of the U.S. Department of Energy’s Princeton Plasma Physics Laboratory (PPPL), likens the development of fusion energy to finding a cure for cancer. “Just as you need to understand the microbiology that underlies cancer to find a cure for the disease, an understanding of plasma physics is crucial to realize the goal of fusion energy,” he said. “Fusion is the big payoff—the ‘cure’ for the global energy crisis, if you will—but there’s a tremendous amount of science that needs to be done to get there.”

For this reason, PPPL, which is managed by the University, is devoted both to creating new knowledge about the physics of plasmas—ultrahot, charged gases—and to developing practical solutions for the creation of fusion energy. Through the process of fusion, which is constantly occurring in the sun and other stars, energy is created when the nuclei of two lightweight atoms, such as those of hydrogen, combine in a plasma at very high temperatures. When this happens, a burst of energy is released, which could theoretically be used to generate electricity.

In a series of experiments at the lab, PPPL researchers are expanding understanding of how plasmas behave and how they can be used to create fusion energy. The largest of these experiments, the National Spherical Torus Experiment (NSTX), began in 1999. As in many other fusion experiments, the plasmas in NSTX are confined using magnetic fields and walls designed to withstand the heat from plasmas with temperatures that exceed 100 million degrees Celsius (to date, NSTX plasmas have attained temperatures of 60 million degrees Celsius). But in contrast to most fusion experiments, which confine plasmas in a donut-like shape, the plasmas in NSTX are spherical in shape with a hole through the center.

Recent results from NSTX are advancing the understanding of plasma behavior, offering insights into what causes turbulence and how to mitigate harmful interactions between the plasma and the walls that confine it. Both turbulence and plasma-wall interactions can result in a major loss of heat from the plasma, which causes a plasma to terminate, or fall apart. When this happens, the energy in the plasma is dumped on the walls that surround it and is no longer useful for the creation of fusion energy.

PPPL researchers Wayne Solomon and Stanley Kaye have studied plasma rotation and the way that momentum is transported from one part of the plasma to another in NSTX. By measuring changes in plasma rotation at various locations in the plasma, the team calculated the components of momentum transport. Solomon and Kaye also joined PPPL theorists Weixing Wang, T. S. Hahm, and Greg Rewoldt in identifying a type of turbulence specific to fusion plasmas. Using computer-based simulations, members of the team discovered that forces arising from turbulence in the plasma’s electric field can transport rotation. Because rotation increases plasma stability, these advances may be beneficial for plasma performance.

In another project, PPPL physicist Ernesto Mazzucato and his colleagues have delved deeper into the nature of turbulence by scattering electromagnetic waves off of turbulent eddies in rotating plasmas. Their findings suggest that turbulence is excited by the non-uniformity of the temperature of the electrons in the plasma, and that this turbulence can lead to significant transport of heat from the plasma. When heat is lost rapidly from a plasma, it is difficult to sustain fusion, so methods to prevent heat loss are crucial for producing fusion energy. Toward this end, NSTX researchers have also shown that heat transport can be somewhat reduced by carefully adjusting the magnetic field that cages the plasma to confine the heat optimally.

In addressing the plasma-wall interaction problem, experiments in NSTX have shown that applying a thin film of lithium (the lightest metallic element) on the walls that confine the plasma can dramatically alter the properties of the plasma, such as temperature and the ability to stay hot.

In most instances when particles from a hot plasma hit the walls that confine it, some of the wall material—often graphite in fusion experiments—vaporizes and turns into a gas that is cooler than the plasma. This gas then enters the plasma, cooling its edges and creating a plasma that is much hotter in the center than on the periphery. This temperature difference creates turbulence, which ultimately lowers the temperature of the entire plasma.

Lithium has the special property of absorbing particles so that no cold gas enters the plasma. Thus, temperature remains more uniform, turbulence is reduced, and the whole plasma stays hot—three important characteristics for the creation of fusion energy.

Additionally, PPPL collaborator Rajesh Maingi of Oak Ridge National Laboratory found that the lithium film also stabilizes edge-localized instabilities—repetitive plasma disturbances...
that create large pulses of heat on the materials in contact with the plasma. Unchecked, these instabilities could damage wall surfaces in more powerful devices.

Beginning in 2012, NSTX will be offline for two years as it undergoes a major upgrade that will dramatically increase the machine’s capabilities by allowing for a doubling of the amount of current that flows through the plasma and a quintupling of the duration of each plasma from one second to five seconds. The upgrade, which includes the installation of superior magnets and the addition of a second neutral beam injector—a system in which a beam of fast-moving neutral atoms are used to heat the plasma—will also increase the heat flux experienced by the walls that confine the plasma to something on the order of 10 million watts per square meter. For a frame of reference, this is roughly equivalent to the amount of heat that a spacecraft encounters upon re-entering the Earth’s atmosphere. The key difference, however, is that a spacecraft need only withstand such extreme abuse for a short amount of time whereas the walls that confine plasmas must be able to take the heat indefinitely.

“This upgrade will advance all three of the NSTX missions—to understand and control the interface between plasmas and the surrounding materials; to develop a candidate plasma for a next-generation fusion energy experimental power generation facility; and to study the basic physics of how to confine plasmas using magnetic fields,” Prager said.

In addition to NSTX, PPPL in 2008 launched another fusion energy experiment known as the Lithium Tokamak Experiment (LTX). An exploratory experiment, LTX enables the detailed study of how lithium walls can provide greater plasma stability and control.

A variety of smaller experiments that focus on basic plasma physics are also underway at the lab. The Magnetic Reconnection Experiment (MRX) enables researchers to study the phenomenon of magnetic reconnection, which converts magnetic energy to kinetic and thermal energy in plasmas, both in the laboratory and in outer space.

In plasmas, charged particles, such as ions and electrons, move along magnetic field lines like trains along railroad tracks. But these magnetic field lines can explosively tear and reconnect, as if two parallel train tracks suddenly split and then rejoined in an overlapping pattern. In plasmas, this process, called magnetic reconnection, results in a final magnetic field that is very different from the one that existed before the magnetic explosions.

In MRX, researchers led by PPPL physicists Masaaki Yamada and Hantao Ji have made the first positive identifications of how electrons behave near the points of tearing and reconnection using detailed measurements of the reconnection site in a controlled environment. Their results suggest that the two-dimensional models used to simulate electron behavior under these conditions may be missing important three-dimensional effects that play an important role in the speed of reconnection. The work has implications both for astrophysics and the development of fusion energy.

Another project, the Paul Trap Simulator Experiment (PTSX), is a compact, three-meter-long cylindrical laboratory experiment. PTSX enables scientists to simulate conditions and experiments that take place in particle accelerators that are several kilometers long because the dynamics of particles in both systems are described by the same set of equations. The experiment is led by Professor of Astrophysical Sciences Ronald Davidson and PPPL scientist Erik Gilson.

In PTSX, experimenters can study how particles travel through a multi-kilometer accelerator by observing how the size of a beam of particles changes over time as it resides in a three-meter-long cylinder. In a particle accelerator, the magnets used to accelerate the particles inevitably are imperfectly aligned, leading to “errors” in the magnetic field. In recent PTSX experiments, these errors have been simulated by adding white noise to the electric field that is applied to a plasma. By enabling increased understanding of error-related effects, PTSX may inform the design of current and future high-energy physics experiments.

“For nearly 60 years, Princeton has been a world leader in research on magnetic fusion energy and the University has trained a large contingent of the active researchers in the field,” said Dean for Research A. J. Stewart Smith.

“We are delighted that the U.S. Department of Energy continues to entrust Princeton with the management of the laboratory, especially as the need to create clean energy solutions for the future intensifies exponentially. Though the challenges going forward are daunting, the laboratory embraces them as it takes on leadership and partnership roles on the national and international scene, such as in ITER, the large international fusion experiment currently under construction in France.”
More than $27 million in Recovery Act funding supports University research

The American Recovery and Reinvestment Act (ARRA), approved by Congress on Feb. 13, 2009, provided a significant influx of research funding to the University, amounting to more than $27 million supporting some 70 projects.

The Recovery Act funding—from the Air Force Office of Scientific Research, the U.S. Department of Energy, the National Institute of Standards and Technology, the National Institutes of Health, and the National Science Foundation—went toward endeavors in numerous fields, including energy, mathematics, engineering, meteorology, computer science, politics, and neuroscience. The ARRA-funded projects at Princeton are of varying lengths, beginning in 2009 and 2010 and extending one year to five years, with several projects continuing through 2013. These awards are supporting a variety of initiatives at Princeton, including the preservation and creation of graduate and postdoctoral research assistantships.

President Shirley M. Tilghman said, “The investment in scientific research through the American Recovery and Reinvestment Act has accelerated the pace of discovery at a time when scientific innovation is not just important—it is essential—for the short-term economic recovery and the long-term economic growth and prosperity of our country. In addition to sustaining and creating thousands of jobs today, both in the scientific workforce and in the industries that support and draw strength from the research enterprise, Recovery Act funding is unleashing waves of innovation that will transform existing industries and lay the foundation for new ones, increasing American global competitiveness at this critical moment in time.”

In a November 2009 news conference on Capitol Hill, Emily Carter, a Princeton professor of engineering and applied mathematics, said that prior to the passage of ARRA, basic research in engineering and physical sciences had been starved for a quarter of a century.

“With one fell swoop, this bill, the recovery and reinvestment bill, really has changed the tone among the whole scientific community,” Carter said. She also spoke about the potential for basic research to inform economic growth through the commercialization of inventions.

“Science ultimately produces jobs,” she said. “It produces jobs today, and it produces jobs down the road through innovation.”

The allocation of $21.5 billion in the Recovery Act to support research had roots in the 2008 “Innovation Agenda” roundtable at Princeton. Arranged by Tilghman, U.S. Rep. Nancy Pelosi, then Speaker of the House, and U.S. Rep. Rush Holt, the event was designed to highlight the importance of basic research in science and technology as a means to create jobs and bolster the economy.
As part of a U.S. Department of Energy Early Career Research Program, Jong-Kyu Park, a staff research physicist at the Princeton Plasma Physics Laboratory, received $2.5 million over five years to further his work on creating a numerical tool to calculate the effects of applying small-amplitude, three-dimensional magnetic fields to fusion devices called tokamaks. These magnetic fields can significantly improve the ability of tokamak vessels to contain fusion reactions.

Funded by a $993,000 National Institutes of Health Challenge Grant through the American Recovery and Reinvestment Act, Lynn Enquist, a professor in Princeton's Department of Molecular Biology and the Princeton Neuroscience Institute, is leading an effort to use genetically engineered viruses as explorers that travel throughout the nervous system, tracing the connections between neurons and reporting on their activity along the way.
Inaugural Schmidt Fund awards enable innovative explorations in sensors and electronics

A project that could enable the development of revolutionary electronics and a separate project that could dramatically improve diabetes monitoring and treatment are the first two research efforts to be supported at Princeton from the Eric and Wendy Schmidt Transformative Technology Fund.

Google CEO and Princeton alumnus Eric Schmidt and his wife, Wendy, created the $25 million endowment fund at Princeton in 2009 to support the advancement of science and engineering through the development and use of entirely new technologies.

The winning research efforts will be led by Ali Yazdani, a professor of physics, and Claire Gmachl, a professor of electrical engineering and director of the University’s Mid-Infrared Technologies for Health and the Environment Center (MIRTHE). Yazdani will lead a collaborative team of five faculty members and their research groups to explore the use of exotic insulators in electronic and optical applications. Gmachl will direct a partnership to develop “clip-on” medical sensors to enable non-invasive, continuous glucose monitoring.

“...Yazdani's work could enable the development of entirely new classes of electronics, and Gmachl's non-invasive glucose-monitoring devices could dramatically improve the lives of millions of people around the globe. Such tremendous potential for reward does carry with it some risk, and we are grateful to the Schmidts for their foresight in recognizing the need to fund projects of this nature, which have the capacity to yield pathbreaking advances in science and engineering.”

The fund was established to allow Princeton’s scientists and engineers to explore truly innovative ideas that might include breakthroughs that traditional funding sources would consider too risky to support.

Yazdani’s partners include Nai Phuan Ong, the Eugene Higgins Professor of Physics and director of the Princeton Center for Complex Materials; Robert Cava, the Russell Wellman Moore Professor of Chemistry; Associate Professor of Physics M. Zahid Hasan; and Assistant Professor of Physics Jason Petta.

In recent years, this group has spearheaded many of the experimental breakthroughs in the burgeoning field of topological insulators, positioning them at the forefront of the knowledge frontier. Topological insulators are highly unusual materials featuring interiors that do not conduct electricity and metallic surfaces that are highly conductive, owing to the presence of special electrons that behave in extraordinary ways. The juxtaposition of non-conducting interiors and so-called “topological” surface states confers upon these insulators a host of exotic electrical, magnetic, and optical properties with vast potential for exploitation in next-generation devices such as optical detection applications, novel superconducting technologies, and “topological” quantum computers—machines with computing capabilities far superior to today’s devices that would harness the unusual behavior of electrons to process information.

To date, members of this collaborative team have led the charge to demonstrate the existence of “topological” surface states in a variety of compounds and to identify some of their fundamental properties. These include excellent electrical conductivity and an unusually large electrical response to the absorption of light.

With a $700,000 award from the Schmidt Fund, the group will pursue a wide range of experiments to demonstrate the utility of topological insulators for electronics and optical applications. Their research plans include the purification of topological insulator materials, the fabrication of nanowires from topological insulators, and a series of experiments to explore more fully the magneto-electric, optical, and thermal properties of the materials.

Gmachl will collaborate with Assistant Professor of Electrical Engineering Gerard Wysocki to develop fingertip sensors for diabetics that measure blood glucose levels as quickly and painlessly as pulse oximeters measure oxygen saturation in the blood.

The diabetes epidemic has reached epic proportions, affecting nearly 10 percent of Americans and more than 200 million people worldwide. According to the World Health Organization, the global epidemic caused more than one million deaths in 2005, and this figure is projected to double by 2030. The effective management and treatment of the disease hinges on the careful monitoring of levels of blood glucose, or blood sugar, with the frequency of...
Glucose measurement being tightly coupled to the successful management of the condition. Efforts to develop non-invasive laser sensors for glucose testing have been stymied to date because glucose does not have distinguishing optical features in the visible and near-infrared ranges of the spectrum, the region in which light passes through human tissue easily and for which sensitive photo-detectors have already been developed.

With a $500,000 award from the Schmidt Fund, Gmachl and Wysocki will build on Gmachl’s pioneering work on the development of quantum cascade lasers, which emit light in the mid-infrared region of the spectrum, where glucose has characteristic spectral features that distinguish it from other major tissue components, including water, urea, and albumin. Additionally, they will draw upon Wysocki’s expertise in the development of highly sensitive, compact optical sensor systems.

Their research plans include the development of quantum cascade lasers that emit light at the precise wavelengths needed for glucose testing as well as the creation of photon detectors, electronics, and software that can be incorporated into a clip-on sensor for the fingertip or earlobe that can serve as a prototype for commercialization.

Gmachl and Yazdani’s projects were selected through a campuswide competition under the auspices of the University’s dean for research.

“The response to the Schmidt Fund call for proposals was extraordinary, and we were frankly overwhelmed by the quality and innovativeness of the proposed projects,” said Dean for Research A. J. Stewart Smith. “After a detailed internal review, we also consulted external experts to advise us how they would place the promise, potential, and risk of these efforts on the world scene. The ideas and plans put forth by these physicists, chemists, and engineers have enormous potential for broad and transformative impact. It is wonderful that the generosity and insight of the Schmidts has given the University the capacity to invest in projects of this nature, and it is inspiring to imagine the breakthroughs that may result from these endeavors.

“Based on the experience gained in the inaugural competition, early in the new year [2011] we shall be announcing the next call for proposals to the Schmidt Fund,” Smith added. “I am completely confident that the depth and breadth of ideas in the Princeton community will lead to future awards as compelling as the ones we announce today.”

Schmidt earned a BSE in electrical engineering from Princeton in 1976 and served as a Princeton trustee from 2004 to 2008.
### Memberships and Fellowships

<table>
<thead>
<tr>
<th>Organization</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Academy of Arts and Sciences</td>
<td>Carles Boix, Robert Garrett Professor in Politics (2010)</td>
</tr>
<tr>
<td></td>
<td>Adam Burrows, professor of astrophysical sciences (2010)</td>
</tr>
<tr>
<td></td>
<td>Paul DiMaggio, the A. Barton Hepburn Professor of Sociology and Public Affairs (2009)</td>
</tr>
<tr>
<td></td>
<td>Lynn Enquist, the Henry L. Hillman Professor in Molecular Biology (2010)</td>
</tr>
<tr>
<td></td>
<td>Hal Foster, the Townsend Martin, Class of 1917, Professor of Art and Archaeology (2010)</td>
</tr>
<tr>
<td></td>
<td>David Huse, professor of physics (2010)</td>
</tr>
<tr>
<td></td>
<td>William Jordan, the Dayton-Stockton Professor of History (2009)</td>
</tr>
<tr>
<td></td>
<td>Chung Law, the Robert H. Goddard Professor of Mechanical and Aerospace Engineering (2010)</td>
</tr>
<tr>
<td></td>
<td>James Marrow, professor of art and archaeology emeritus (2010)</td>
</tr>
<tr>
<td></td>
<td>Nolan McCarty, the Susan Dod Brown Professor of Politics and Public Affairs (2010)</td>
</tr>
<tr>
<td></td>
<td>James McPherson, the George Henry Davis 1886 Professor of American History Emeritus (2009)</td>
</tr>
<tr>
<td></td>
<td>Guy Nordenson, professor of architecture (2009)</td>
</tr>
<tr>
<td></td>
<td>Wolfgang Pesendorfer, the Theodore A. Wells ’29 Professor of Economics (2010)</td>
</tr>
<tr>
<td></td>
<td>Philip Pettit, the Laurance S. Rockefeller University Professor of Politics and the University Center for Human Values (2009)</td>
</tr>
<tr>
<td></td>
<td>Susan Fiske, the Eugene Higgins Professor of Psychology (2009)</td>
</tr>
<tr>
<td></td>
<td>Markus Brunnermeier, the Edwards S. Sanford Professor of Economics (2010)</td>
</tr>
<tr>
<td>American Association for the Advancement of Science</td>
<td>Avinash Dixit, the John J. F. Sherrerd ’52 University Professor of Economics Emeritus (2009)</td>
</tr>
<tr>
<td></td>
<td>Rosemary Grant, retired senior biologist (2009)</td>
</tr>
<tr>
<td></td>
<td>Alejandro Portes, the Howard Harrison and Gabrielle Snyder Beck Professor of Sociology (2009)</td>
</tr>
<tr>
<td>American Philosophical Society</td>
<td>John Simon Guggenheim Memorial Foundation</td>
</tr>
</tbody>
</table>

### Tilghman honored with 2010 international science prize

Princeton President Shirley M. Tilghman, a world-renowned scholar and leader in the field of molecular biology, was honored with the 2010 Henry G. Friesen International Prize in Health Research. The annual prize was established in 2005 by the Friends of Canadian Institutes of Health Research in collaboration with the Canadian Academy of Health Sciences. It recognizes exceptional innovation by a visionary health leader of international stature.

Tilghman, a native of Canada, received her Honors B.Sc. in chemistry from Queen’s University in Kingston, Ontario, in 1968 and obtained her Ph.D. in biochemistry from Temple University in Philadelphia in 1975. During postdoctoral studies at the National Institutes of Health, she made a number of groundbreaking discoveries while participating in cloning the first mammalian gene.

Before being named Princeton’s president in 2001, Tilghman served as a faculty member at the University for 15 years. She came to Princeton in 1986 as the Howard A. Prior Professor of the Life Sciences and two years later joined the Howard Hughes Medical Institute as an investigator. In 1998, she became the founding director of Princeton’s multidisciplinary Lewis-Sigler Institute for Integrative Genomics.

Tilghman chaired Princeton’s Council on Science and Technology, which encourages the teaching of science and technology to students outside the sciences, and she initiated the Princeton Postdoctoral Teaching Fellowship.

A member of the National Research Council’s committee that set the blueprint for the U.S. effort in the Human Genome Project, Tilghman also was one of the founding members of the National Advisory Council of the Human Genome Project Initiative for the National Institutes of Health.
Krugman wins Nobel

Princeton economist Paul Krugman, acclaimed in his field for insights into international trade patterns that overturned longheld theories about the global economy before he rose to popular distinction as a media columnist and commentator, was awarded the 2008 Nobel Prize in economics.

“By having shown the effects of economies of scale on trade patterns and on the location of economic activity, his ideas have given rise to an extensive reorientation of the research on these issues,” the Royal Swedish Academy of Sciences noted in announcing the award.

Beginning in 1979, Krugman proposed a new model that provided a theory for the effects of globalization and free trade. It offered a better explanation than the well-established theory of foreign trade that certain countries have a comparative advantage over others in more effectively producing particular goods based on factors such as climate, natural resources, or supplies of labor or capital.

Krugman recognized that the traditional theory did not fully explain modern trends that showed international trade becoming increasingly concentrated among smaller numbers of producers and nations. His work shed light on key economic issues such as why countries import and export the same goods, how companies decide where to locate, how people decide where to live, and why dense urban areas become centers of economic activity while existing alongside sparsely populated rural areas.

Caryl Emerson, the A. Watson Armour III University Professor of Slavic Languages and Literatures (2009)
Jianqing Fan, the Frederick L. Moore, Class of 1918, Professor in Finance (2009)
Denis Feeney, the Giger Professor of Latin (2009)
Susan Fiske, the Eugene Higgins Professor of Psychology (2009)
Steven Gubser, professor of physics (2009)
Bernard Haykel, professor of Near Eastern studies (2010)
Daniel Heyman, lecturer in visual arts and the Lewis Center for the Arts (2010)
Joshua Katz, professor of classics (2010)
Igor Klebanov, professor of physics (2010)
Philip Pettit, the Laurence S. Rockefeller University Professor of Politics and the University Center for Human Values (2010)
Alexander Todorov, associate professor of psychology and public affairs (2010)
Muhammad Zaman, the Robert H. Niehaus ’77 Professor of Near Eastern Studies and Religion (2009)
Sigman, Zoli win MacArthur ‘genius grants’

Daniel Sigman, a Princeton biogeochemist who has conducted pioneering work exploring the large-scale systems that have supported life on the planet throughout the millennia, was selected as a 2009 MacArthur Fellow.

The John D. and Catherine T. MacArthur Foundation fellowships, known informally as “genius grants,” honor the winners for their creativity, originality, and potential to make important contributions to the future. Each award winner receives a $500,000 no-strings-attached grant over a five-year period.

Sigman is searching for the underlying mechanisms that explain how life on Earth has been sustained through a web of chemical, biological, and physical forces over time. In doing so, he has developed methods to track the flow of elements vital to life, such as nitrogen and carbon, today and in the past. His methods for analyzing isotopes of nitrogen have helped show how different processes in the ocean’s nitrogen cycle respond to one another. His research also focuses on the role of the ocean’s “biological carbon pump”—in which the sinking of dead algae sequesters carbon dioxide in the deep ocean—in Earth’s climate history. Using deep-sea sediment cores from throughout the world’s oceans, Sigman is carefully reconstructing the contribution of ocean biology to the carbon cycle over time.

Also chosen was Theodore Zoli, a 1988 alumnus and a visiting lecturer in Princeton’s Department of Civil and Environmental Engineering since 2003. Zoli is a structural engineer who has developed novel ways of protecting transportation infrastructure in the event of natural and man-made disasters.
Prizes

American Academy of Arts and Letters

Stanley Allen, dean of the School of Architecture and the George Dutton ’27 Professor of Architecture: 2009 Academy Award in Architecture

Susan Stewart, the Avalon Foundation University Professor in the Humanities: 2009 Academy Award in Literature

Barbara White, professor of music: 2009 Academy Award in Music

National Academy of Sciences

Bonnie Bassler, the Squibb Professor in Molecular Biology: 2011 Richard Lounsbery Award “for her pioneering discoveries of the universal use of chemical communication among bacteria and the elucidation of structural and regulatory mechanisms controlling bacterial assemblies”

Paul Reider, lecturer in the Department of Chemistry: 2011 NAS Award for Chemistry in Service to Society “for his contributions to the discovery and development of numerous approved drugs, including those for treating asthma and for treating AIDS”

American Chemical Society

Robert Cava, the Russell Wellman Moore Professor of Chemistry: 2011 ACS Award in Inorganic Chemistry

David MacMillan, the A. Barton Hepburn Professor of Organic Chemistry: 2011 ACS Award for Creative Work in Synthetic Organic Chemistry

François Morel, the Albert G. Blanke Jr. Professor of Geosciences: 2011 ACS Award for Creative Advances in Environmental Science and Technology

Edward Taylor, the A. Barton Hepburn Professor of Organic Chemistry Emeritus: 2010 Alfred Burger Award in Medicinal Chemistry

American Geophysical Union

Ignacio Rodríguez-Iturbe, the James S. McDonnell Distinguished University Professor of Civil and Environmental Engineering: 2009 William Bowie Medal for “outstanding contributions to fundamental geophysics and for unselfish cooperation in research”

American Mathematical Society

Maryam Mirzakhani, former professor of mathematics: 2009 Leonard M. and Eleanor B. Blumenthal Award for the Advancement of Research in Pure Mathematics

American Physical Society

Michael Aizenman, professor of physics and mathematics: 2010 Dannie Heineman Prize for Mathematical Physics

Lynn Loo, associate professor of chemical and biological engineering: 2010 John H. Dillon Medal “to recognize outstanding research accomplishments by young polymer physicists who have demonstrated exceptional research promise early in their careers”

Alexander Polyakov, the Joseph Henry Professor of Physics: 2011 Lars Onsager Prize “to recognize outstanding research in theoretical statistical physics including the quantum fluids”

Princeton scientists win Shaw Prize for helping map the universe

Astrophysicists Lyman Page and David Spergel won the 2010 Shaw Prize for their pioneering work on the Wilkinson Microwave Anisotropy Probe, the NASA satellite known as WMAP that has contributed to breakthroughs in better understanding the shape, makeup, and age of the universe.

Page, the Henry DeWolf Smyth Professor of Physics, and Spergel, the Charles A. Young Professor of Astronomy on the Class of 1897 Foundation, were recognized, along with Charles Bennett of Johns Hopkins University, “for their leadership of the Wilkinson Microwave Anisotropy Probe (WMAP) experiment, which has enabled precise determinations of the fundamental cosmological parameters, including the geometry, age, and composition of the universe.”

Page and Spergel said the award honors the work of the WMAP team and a group of Princeton contributors, including the late physicists Robert Dicke and David Wilkinson, and Norm Jarosik, a senior research physicist. The experimental program to measure the cosmic microwave background radiation—the remnants of the Big Bang—began at the University more than a decade ago.

The program established that the cosmos is 13.75 billion years old, with a degree of error of 1 percent. WMAP also showed that normal atoms make up only 4.6 percent of today’s cosmos, and it verified that most of the universe consists of two entities scientists don’t yet understand: Dark matter, which makes up 23 percent of the universe, is one of the entities, and is a material that has yet to be detected in the laboratory; and dark energy is a gravitationally repulsive entity that may be a feature of the vacuum itself. WMAP confirmed its existence and determined that it fills 72 percent of the cosmos. Another important WMAP breakthrough involves a hypothesized cosmic “growth spurt” called inflation. For decades, cosmologists have suggested that the universe went through an extremely rapid growth phase within the first trillionth of a second it existed. WMAP’s observations support the notion that inflation did occur, and its detailed measurements now rule out several well-studied inflation scenarios while providing new support for others.

WMAP acquired its final scientific data on Aug. 20, 2010. On Sept. 8, 2010, the satellite fired its thrusters, left its working orbit, and entered into a permanent parking orbit around the sun, completing its mission as planned.
Gunn awarded 2009 National Medal of Science

James Gunn, the Eugene Higgins Professor of Astronomy at Princeton, received a 2009 National Medal of Science for his sweeping contributions to modern stargazing, from theory to observation, to gadget-building.

The medal is the highest honor bestowed by the U.S. government upon scientists and engineers.

“These [researchers] are national icons, embodying the very best of American ingenuity and inspiring a new generation of thinkers and innovators,” President Barack Obama said.

“Theyir extraordinary achievements strengthen our nation every day—not just intellectually and technologically but also economically, by helping create new industries and opportunities that others before them could never have imagined.”

Gunn’s early theoretical work helped establish the current understanding of how galaxies form, as well as the properties of intergalactic space. He also suggested important observational tests to confirm the presence of dark matter in galaxies and developed plans for one of the first uses of digital camera technology for space observation.

His digital camera engineering skills were crucial both for the Hubble Space Telescope and the Sloan Digital Sky Survey, a project he originated that has produced the deepest, most comprehensive map of the heavens ever made.

He is regarded as one of the world’s premier designers of detection instruments. One noted Gunn creation is the 700-pound camera for the Sloan Digital Sky Survey that he built in the basement of the University’s Peyton Hall over six years. The camera, one of the most complex imaging instruments ever developed for astronomy, currently is connected to the telescope at Apache Point, perched atop the Sacramento Mountains in New Mexico.

The Gunn-designed camera has helped scientists using the Sloan telescope to confirm the existence of dark energy, the mysterious force believed to be causing the universe’s expansion. Scientists working on the project have made many discoveries, including detecting the most distant quasar ever, and finding the most massive structure in the universe, a huge collection of galaxies called the “Great Wall.”

Frans Pretorius, assistant professor of physics: 2010 Aneesur Rahman Prize for Computational Physics

Michael Romalis, professor of physics: 2011 Francis M. Pipkin Award “to honor exceptional research accomplishments by a young scientist in the inter-disciplinary area of precision measurement and fundamental constants”

Paul Steinhardt, the Albert Einstein Professor in Science: 2010 Oliver E. Buckley Condensed Matter Prize

A. J. Stewart Smith, dean for research and the Class of 1909 Professor of Physics: 2011 W.K.H. Panofsky Prize in Experimental Particle Physics

James Stone, professor of astrophysical sciences and applied and computational mathematics: 2011 Aneesur Rahman Prize for Computational Physics

Salvatore Torquato, professor of chemistry and the Princeton Institute for the Science and Technology of Materials: 2009 David Adler Lectureship Award

Aneesur Rahman Prize for Computational Physics

American Psychological Association

Jonathan Cohen, the Eugene Higgins Professor of Psychology: 2010 Distinguished Scientific Contribution Award

Susan Fiske, the Eugene Higgins Professor of Psychology: 2010 Distinguished Scientific Contribution Award

American Political Science Association

Larry Bartels, the Donald E. Stokes Professor in Public and International Affairs: 2009 Gladys M. Kammerer Award “for the best political science publication in the field of U.S. national policy” for “Unequal Democracy: The Political Economy of the New Gilded Age” (Princeton University Press)

American Society of Mechanical Engineers

Philip Holmes, the Eugene Higgins Professor of Mechanical and Aerospace Engineering: 2009 Lyapunov Award “to recognize lifelong contributions to the field of nonlinear dynamics”
American Sociological Association

Alejandro Portes, the Howard Harrison and Gabrielle Snyder Beck Professor of Sociology: 2010 W.E.B. Du Bois Career of Distinguished Scholarship Award

Ecological Society of America

Simon Levin, the George M. Moffatt Professor of Biology: 2010 Eminent Ecologist Award

Stephen Pacala, the Frederick D. Petrie Professor in Ecology and Evolutionary Biology: 2010 Robert H. MacArthur Award “for meritorious contributions to ecology”

Franklin Institute

Ingrid Daubechies, the William R. Kenan Jr. Professor of Mathematics and Applied and Computational Mathematics: 2011 Benjamin Franklin Medal in Electrical Engineering

Howard Hughes Medical Institute

Yigong Shi, visiting research collaborator in molecular biology: Investigator (2009)

David Stern, professor of ecology and evolutionary biology: Investigator (2009)

Institute of Electrical and Electronics Engineers

John Hopfield, the Howard A. Prior Professor in the Life Sciences Emeritus: 2009 Frank Rosenblatt Award “for outstanding contribution to the advancement of the design, practice, techniques, or theory in biologically and linguistically motivated computational paradigms”

Institute of Electrical and Electronics Engineers Computer Society

Roberto Car, the Ralph W. *31 Dornte Professor in Chemistry: 2009 Sidney Fernbach Award “for outstanding contributions in the application of high performance computers using innovative approaches”

Library of Congress

Peter Brown, the Philip and Beulah Rollins Professor of History: 2008 Kluge Prize for Lifetime Achievement in the Study of Humanity

National Book Critics Circle

Joyce Carol Oates, the Roger S. Berlind ’52 Professor in the Humanities: 2009 Ivan Sandrof Lifetime Achievement Award

Organization of American Historians


Phi Beta Kappa Society

Stanley Katz, lecturer with the rank of professor in public and international affairs: 2010 Fellows Award to “honor an individual who has demonstrated scholarly achievement and excellence in his or her chosen field”

Renaissance Society of America

François Rigolot, the Meredith Howland Pyne Professor of French Literature: 2011 Paul Oskar Kristeller Lifetime Achievement Award

Society for Industrial and Applied Mathematics

Weinan E, professor of mathematics and applied and computational mathematics: 2009 Ralph E. Kleinman Prize “for outstanding research, or other contributions, that bridge the gap between mathematics and applications”

Society of Porphyrins and Phthalocyanines

John Groves, the Hugh Stott Taylor Chair of Chemistry: 2010 Hans Fischer Career Award

Sterling and Francine Clark Art Institute

Hal Foster, the Townsend Martin, Class of 1917, Professor of Art and Archaeology: 2010 Clark Prize for Excellence in Arts Writing

The Wiley Foundation

Bonnie Bassler, the Squibb Professor in Molecular Biology: 2009 Wiley Prize in Biomedical Sciences

**Lindenstrauss received 2010 Fields Medal**

Elon Lindenstrauss, a Princeton professor of mathematics from 2004 until 2010, was awarded one of the 2010 Fields Medals, widely considered to be the math world’s equivalent of the Nobel Prize. Subsequent to receiving this honor, Lindenstrauss joined the faculty of his alma mater, the Hebrew University of Jerusalem in Israel.

Lindenstrauss studies ergodic theory, dynamical systems, and number theory. Ergodic theory describes the statistical and qualitative behavior of measurable group actions on mathematical constructs known as measure spaces.

Originated in the 1930s by mathematicians including John von Neumann, it has grown to be of wide interest to researchers, and has applications to number theory, differential geometry, statistical mechanics, and functional analysis.

In being honored with the Fields Medal, Lindenstrauss was cited for developing “extraordinarily powerful theoretical tools in ergodic theory, a field of mathematics initially developed to understand celestial mechanics. He then used them, together with his deep understanding of ergodic theory, to solve a series of striking problems in areas of mathematics that are seemingly far afield.”

**Botstein awarded 2010 Albany Prize**

David Botstein, director of Princeton’s Lewis-Sigler Institute for Integrative Genomics, received the 2010 Albany Medical Center Prize in Medicine for his leading role in mapping the human genome.

Botstein shared the honor with co-recipients Francis Collins, director of the National Institutes of Health, and Eric Lander, a Princeton alumnus and director of the Broad Institute of the Massachusetts Institute of Technology and Harvard University. The annual award is accompanied by a $500,000 prize shared by recipients.

“These three scientists undoubtedly will hold a special place in the history of science and medicine as primary initiators of a profound revolution in human development,” said James Barba, president and chief executive officer of the Albany Medical Center and chair of the award’s national selection committee. “This is because they unlocked and opened the door that had previously barred us from understanding disease processes at the most basic genetic level. Their discoveries promise to lead to a wide range of advances including the development of person- and disease-specific medicines that should be much more effective at combating a wide range of diseases.”
Husband-and-wife team wins Kyoto Prize

Princeton University’s Peter and Rosemary Grant, whose legendary explorations on the bleak Galápagos island of Daphne Major over nearly four decades have produced an array of dazzling insights into evolutionary theory, received the 2009 Kyoto Prize.

The biologists were the first husband-and-wife team to win in the 25-year history of the prize. They were cited both for their scientific ideas and their personal characteristics that have shaped those achievements.

“The Grants’ empirical research has made the most important contribution since Darwin toward making evolutionary biology a science in which proof is possible,” the Inamori Foundation stated in a news release announcing the award.

In their dogged study of a population of birds popularly known as “Darwin’s finches,” the Grants won renown for detecting and recording evolution in action, and proving and extending the theories of pioneering evolutionist Charles Darwin. Working in the Galápagos, the most celebrated place in the study of evolution, they have conducted extensive surveys of the totemic birds, whose beaks spurred the great naturalist’s first allusions to what would be his world-shattering theory.

International Recognition

**Abdus Salam International Centre for Theoretical Physics**

**Roberto Car**, Ralph W. ’31 Dornte Professor in Chemistry: 2009 Dirac Medal for “significant contributions to theoretical physics”

**Alexander von Humboldt Foundation**

**Michael Smith**, the McCosh Professor of Philosophy: 2009 Humboldt Research Award

**Roberto Car**, the Ralph W. ’31 Dornte Professor in Chemistry: 2009 Humboldt Research Award

**British Government**


**Linda Colley**, the Shelby M.C. Davis 1958 Professor of History: Commander of the Order of the British Empire (2009)

**French Government**

**Victor Brombert**, the Henry Putnam University Professor of Romance Languages and Literatures and Comparative Literature emeritus: Legion of Honor (2009)

**Marie-Héléne Huet**, the M. Taylor Pyne Professor of French and Italian: Officer in the Order of Academic Palms (2010)

**International Academy of Quantum Molecular Science**

**Emily Carter**, the Gerhard R. Andlinger Professor in Energy and the Environment: Membership (2009)

**International Union of Pure and Applied Physics**

**Rupert Frank**, assistant professor of mathematics: 2009 Young Scientist Prize

**Italian Government**


**Edmund White**, professor of creative writing: 2010 Premio Letterario Internazionale Mondello

**Max Planck Institute for Bioinorganic Chemistry**

**John Groves**, the Hugh Stott Taylor Chair of Chemistry: 2009 Frontiers in Biological Chemistry Award
In the Nation's Service*

“One important reflection of ‘Princeton in the nation’s service’ is the number of our faculty who take one- to two-year leaves of absence to serve in positions in the federal government. As much as we miss them while they are in Washington, it is important for the University to facilitate these opportunities. They allow faculty to both serve their country and return to campus with newly acquired experiences and insights that inform their teaching and research. By interweaving the study and practice of public policy, the worlds of government and higher education are both strengthened: scholarly models are tested in the crucible of political reality while governmental policies and decisions are informed by up-to-date social science research.”

–President Shirley M. Tilghman

Excerpted from “Our Faculty in Washington,” April 7, 2010, President’s Page in the Princeton Alumni Weekly

Christopher Chyba, professor of astrophysical sciences and international affairs: President’s Council of Advisors on Science and Technology (2009– )


Ilyana Kuziemko, assistant professor of economics and public affairs: Deputy assistant secretary for microeconomic analysis, U.S. Department of the Treasury (2009–10)

Jim Leach, the former John L. Weinberg/Goldman Sachs and Co. Visiting Professor of Public and International Affairs: Chairman of the National Endowment for the Humanities (2009–13)

Alexander Mas, professor of economics and public affairs: Chief economist, U.S. Department of Labor (2009–10); associate director for economic policy and chief economist, Office of Management and Budget, Executive Office of the President (2010–11)

Cecilia Rouse, the Theodore A. Wells ’29 Professor of Economics and Public Affairs: Member, President’s Council of Economic Advisors (2009–11)

Anne-Marie Slaughter, the Bert G. Kerstetter ’66 University Professor of Politics and International Affairs: Director, Policy Planning, State Department (2009–11)

Natalie Zemon Davis, the Henry Charles Lea Professor of History Emeritus: 2010 Holberg Prize “for outstanding scholarly work in the fields of the arts and humanities, social sciences, law and theology”

Polish Government

Robert George, the McCormick Professor of Jurisprudence: 2010 Honorific Medal for the Defense of Human Rights of the Republic of Poland

Royal Academy of Engineering

H. Vincent Poor, dean of the School of Engineering and Applied Science and the Michael Henry Strater University Professor of Electrical Engineering: Fellowship (2009)

Royal Society for the Encouragement of Arts, Manufactures and Commerce

Elizabeth Gould, professor of psychology and the Princeton Neuroscience Institute: 2009 Benjamin Franklin Medal “to a global ‘big thinker’ who has shifted public debate in an innovative way and contributed to furthering public discourse on human progress”

Society for Musicology in Ireland

Kofi Agawu, professor of music: 2009 Frank Llewelyn Harrison Medal for musicology

*This list includes current and former members of Princeton’s research community who have served the nation in a variety of capacities, including while on leaves of absence from the University.


Caryl Emerson, the A. Watson Armour III University Professor of Slavic Languages and Literatures: *All the Same the Words Don’t Go Away: Essays on Authors, Heroes, Aesthetics, and Stage Adaptations from the Russian Tradition* (Academic Studies Press, 2010).


Simon Levin, the George M. Moffett Professor of Biology: *Games, Groups, and the Global Good* (Springer, 2009), editor.

Heath Lowry, the Ataturk Professor of Ottoman and Modern Turkish Studies: *In the Footsteps of the Ottomans: A Search for Sacred Spaces & Architectural Monuments in Northern Greece* (Bahçeşehir University, 2009).

Chang-rae Lee, professor of creative writing in the Lewis Center for the Arts: *The Surrendered* (Riverhead, 2010).

**Paul Muldoon**, the Howard G.B. Clark ’21 University Professor in the Humanities and chair of the Lewis Center for the Arts: *Plan B* (Enitharmon Press, 2009), with photographs by Norman McBeath.


**Cornel West**, the Class of 1943 University Professor in the Center for African American Studies: *Brother West: Living and Loving Out Loud, A Memoir* (SmileyBooks, 2009), with David Ritz.

**Sean Wilentz**, the George Henry Davis 1886 Professor of American History: *Bob Dylan in America* (Doubleday, 2010).

**Joyce Carol Oates**, the Roger S. Berlind ’52 Professor in the Humanities: *A Widow’s Story: A Memoir* (Ecco, 2011).


As a world-renowned research university, Princeton seeks to achieve the highest levels of distinction in the discovery and transmission of knowledge and understanding. At the same time, Princeton is distinctive among research universities in its commitment to undergraduate teaching.

From the advancement of mathematical theory and sociological understanding to the development of cleaner-burning fuels and novel electronic devices, research at Princeton aims to expand the frontiers of human knowledge and improve societal well-being.

The Dean for Research supports Princeton’s mission to be one of the leading research universities in the world by uniting people, resources, and opportunities for the creation, preservation, and transmission of knowledge. The Office of the Dean for Research and the offices it oversees—the Office of Corporate and Foundation Relations, the Office of Technology Licensing, and the Office of Research and Project Administration—work together to steward and administer Princeton’s thriving research enterprise. Additionally, the Dean for Research, with the advice of the University Research Board faculty committee, is responsible for the formulation and implementation of policies on sponsored research.

To support the University’s research community and enable Princeton’s scholars to do their best work, the research administration at Princeton is deeply committed to:

- Helping researchers compete effectively for research funding and assisting with the establishment of new partnerships;
- Enabling the transfer of Princeton discoveries into the public domain and protecting University intellectual property rights;
- Setting policies and shaping the University’s research agenda; and
- Providing guidance and oversight to ensure that all research is conducted in an ethical and responsible manner in compliance with University policies and federal regulations.

The Leadership Development Institute is a National Science Foundation-supported project intended to bolster research capacity and strengthen science, technology, engineering, and mathematics research and education at historically black colleges and universities. Organized at the University by the Princeton Center for Complex Materials, the Princeton Institute for the Science and Technology of Materials, and the independent Quality Education for Minorities Network—a nonprofit organization based in Washington, D.C.—the program enabled visiting scientists to collaborate with the Princeton faculty on a project that melded their research interests. As part of the program, Kinesha Harris, an assistant professor of biochemistry at Southern University at Baton Rouge, found that leaves from tropical almond plants native to Nigeria possess anti-microbial properties that might be effective against harmful bacteria.
Facts and figures

The University’s vibrant research community includes investigators at all levels of experience, ranging from the most senior professors to undergraduates who are just beginning their intellectual careers. These dedicated scholars are currently engaged in more than 1,300 sponsored research programs across the disciplines, which involve nearly every department, center, and institute at Princeton.

In addition to the state-of-the-art facilities on campus, Princeton has long-standing collaborations with three of the nation’s premier research laboratories. The University manages and operates the U.S. Department of Energy’s (DOE) Princeton Plasma Physics Laboratory—the only national lab devoted solely to plasma physics and fusion science—and also serves as one of six universities engaged in the management of DOE’s Brookhaven National Laboratory. Princeton also has a cooperative agreement to conduct research at the National Oceanic and Atmospheric Administration’s Geophysical Fluid Dynamics Laboratory (GFDL). Located on the University’s Forrestal Campus, GFDL is one of the world’s foremost climate research and modeling centers.

External support

External funding is the lifeblood that fuels Princeton’s world-class research enterprise. Support for Princeton’s programs has increased in recent years, both in the form of sponsored programs and gifts. The research and education programs enabled by this support range from individual projects to the establishment of major research centers.

Awards from government agencies comprise the lion’s share—around 85 percent—of sponsored research funding. Gifts and grants from corporations and foundations, which often inject a much-needed pulse of targeted funding, complement federal support in important ways. For example, awards from foundations often provide early-stage funding to new research efforts, leveraging nascent programs for future government grants. In the case of more mature research programs, grants from corporations often support the translation of basic discoveries into products and applications for the public domain.

Princeton’s research expenditures—a measure of the amount of sponsored research at the University—have increased over the past five years, growing from $144 million in 2006 to $177 million in 2010. The $250 million in sponsored research awards received in fiscal year 2010 will contribute to the continued robustness of expenditures over the next several years.

Additionally, research expenditures at the U.S. Department of Energy’s Princeton Plasma Physics Laboratory (PPPL), which is managed by the University, average around $80 million annually.

Taken together, research expenditures at Princeton and PPPL totaled more than a quarter of a billion dollars in 2010.


2006–10 Sponsored Project Expenditures (in millions of dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>University</th>
<th>PPPL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>144</td>
<td>81</td>
<td>224</td>
</tr>
<tr>
<td>2007</td>
<td>145</td>
<td>74</td>
<td>219</td>
</tr>
<tr>
<td>2008</td>
<td>151</td>
<td>75</td>
<td>225</td>
</tr>
<tr>
<td>2009</td>
<td>158</td>
<td>75</td>
<td>232</td>
</tr>
<tr>
<td>2010</td>
<td>177</td>
<td>80</td>
<td>257</td>
</tr>
</tbody>
</table>

All numbers rounded

Technology transfer

Each year, around 300 members of the Princeton research community participate in the technology transfer process, ranging from the filing of invention disclosures and patent applications to the licensing of technologies and the creation of start-up companies. Over the past five years, around 80 invention disclosures have been filed each year and the University has been issued between 30 and 40 patents annually. Princeton received nearly $96 million of income from licensed technologies in 2010. Royalties on the sale of Alimta, a blockbuster cancer drug developed by Princeton chemist Edward Taylor in collaboration with scientists at Eli Lilly and Co., comprise a significant portion of this income. Lilly holds an exclusive license for the drug patent.

The Dean for Research is the senior University officer responsible for advancing research at Princeton. The dean oversees the solicitation of research funding, implements Princeton’s research policies, and helps to shape the research priorities of the University.

The Office of Corporate and Foundation Relations builds strategic partnerships with corporations and foundations in support of research and programs across all academic areas.

The Office of Research and Project Administration administers government grants and sponsored research and is responsible for compliance and regulatory matters.

The Office of Technology Licensing promotes technology transfer through the patenting and licensing of discoveries made in Princeton laboratories.

A $10 million gift from the Starr Foundation in 2008 endowed the C.V. Starr Fellows Program in Neuroscience in the Princeton Neuroscience Institute. The visiting fellows program brings established and early career neuroscientists to campus, providing opportunities for early-career scholars to conduct innovative, risk-taking research.

(Image courtesy of Rafael Moneo Valiés Arquitecto)
The Lewis Library, designed by Frank Gehry, opened in 2008 to integrate science holdings.
Why research? We pursue research at Princeton to advance the understanding of our universe and our role in it, to increase fundamental human knowledge, and to serve the public welfare. These endeavors are critical at a time when the world faces daunting challenges of monumental proportions—the energy crisis, climate change, poverty, and infectious diseases, to name just a few—and when life as we know it is constantly altered by the inflow of new knowledge, and by the applications of this knowledge to technology and to culture.

Whether in molecular biology or sociology, theoretical physics or economics, computer science or chemical engineering, the advances enabled by research often have unexpected—indeed, unimaginable—future applications. A new molecule might one day become a new medicine or enable an alternative energy source. A new theory might transform the way we communicate with one another or comprehend the global economy. And the ability to glimpse, and ultimately manipulate, particles on the nanoscale might revolutionize the way we process information.

It would be impossible to overstate the importance of U.S. universities in driving the research engine of our nation and in training the next generation of leaders to thrive in an increasingly technological world. At Princeton, and at peer institutions across the nation, new knowledge, and by the applications of knowledge, and to serve the public welfare. These endeavors are critical at a time when the world faces daunting challenges of monumental proportions—the energy crisis, climate change, poverty, and infectious diseases, to name just a few—and when life as we know it is constantly altered by the inflow of new knowledge, and by the applications of this knowledge to technology and to culture.

Whether in molecular biology or sociology, theoretical physics or economics, computer science or chemical engineering, the advances enabled by research often have unexpected—indeed, unimaginable—future applications. A new molecule might one day become a new medicine or enable an alternative energy source. A new theory might transform the way we communicate with one another or comprehend the global economy. And the ability to glimpse, and ultimately manipulate, particles on the nanoscale might revolutionize the way we process information.

It would be impossible to overstate the importance of U.S. universities in driving the research engine of our nation and in training the next generation of leaders to thrive in an increasingly technological world. At Princeton, and at peer institutions across the nation, new knowledge, and by the applications of knowledge, and to serve the public welfare. These endeavors are critical at a time when the world faces daunting challenges of monumental proportions—the energy crisis, climate change, poverty, and infectious diseases, to name just a few—and when life as we know it is constantly altered by the inflow of new knowledge, and by the applications of this knowledge to technology and to culture.

Whether in molecular biology or sociology, theoretical physics or economics, computer science or chemical engineering, the advances enabled by research often have unexpected—indeed, unimaginable—future applications. A new molecule might one day become a new medicine or enable an alternative energy source. A new theory might transform the way we communicate with one another or comprehend the global economy. And the ability to glimpse, and ultimately manipulate, particles on the nanoscale might revolutionize the way we process information.

It would be impossible to overstate the importance of U.S. universities in driving the research engine of our nation and in training the next generation of leaders to thrive in an increasingly technological world. At Princeton, and at peer institutions across the nation, new knowledge, and by the applications of knowledge, and to serve the public welfare. These endeavors are critical at a time when the world faces daunting challenges of monumental proportions—the energy crisis, climate change, poverty, and infectious diseases, to name just a few—and when life as we know it is constantly altered by the inflow of new knowledge, and by the applications of this knowledge to technology and to culture.