“A research university cannot be great unless it has great science. Columbia is committed to this plan for scientific excellence that brings together leading scholars across disciplines to address the most profound questions of life on our planet.”

—Lee C. Bollinger, Columbia University President
Many of the world’s greatest discoveries have been made in the nine natural sciences departments in Arts and Sciences at Columbia University. Collectively, our faculty members have won numerous Nobel Prizes and are represented in disproportionately high numbers in the National Academy of Sciences and the American Academy of Arts and Sciences. Our faculty hold the highest awards in each of their fields, respectively, including MacArthur Fellows, the Fields Medal, the Shaw Prize, the Cole Prize, the Crafoord Prize, and the National Medal of Science. In many cases Columbia’s science departments are among the top in their areas of study globally, and they have played essential roles in the advancement of science.

Each department’s achievements are impressive. The Departments of Biological Sciences, Chemistry, and Physics played a substantial role in the invention of genetic and cell biology, and pioneered the fields of synthetic chemistry, nanoscience, lasers, and nuclear physics. The Mathematics Department is an academic leader in algebraic geometry, an area of math that lays the foundation for string theory. Columbia is at the forefront of neuroscience research, and many of the natural sciences departments, including Psychology, Statistics, and Biological Sciences, have made significant contributions in this arena. The Earth and Environmental Sciences Department—where the transformative theory of plate tectonics was verified and the term “global warming” was coined—is the top department of its kind in the country. The Astronomy Department was recently ranked as among the top in the country. In just a decade, the Department of Ecology, Evolution and Environmental Biology has positioned itself to forge new scholarship in the crucial field of sustainability.

During this same period, our peers have mounted aggressive campaigns to establish leadership in the sciences. In order to build on our distinguished history, and to maintain and consolidate our preeminence, we have developed a plan to renew Columbia’s science leadership over the next decade. This renewal will be accomplished through groundbreaking research that will expand knowledge and solve critical problems. At the same time, this plan will enhance research opportunities for our undergraduates that will instill critical thinking skills, foster the next generation of scientists, and better inform the public, whose understanding of scientific issues that impact society is essential to a robust democracy.

This plan will improve Columbia’s research competitiveness in an ever-more-difficult federal funding climate, increase diversity in our scientific community, enhance opportunities for technology transfer and commercial partnerships, and build synergistic relationships between science and other intellectual pursuits at Columbia. Given its preeminence in humanistic studies such as law, philosophy, and ethics, Columbia is an intellectually robust community for holistically considering the ideas generated through scientific discovery.

“We set out to bring together our nine science departments under the common goal of building on our strengths, identifying opportunities for great breakthroughs, contributing solutions to the challenges facing our world today, and charting a path to scientific preeminence at Columbia.”

—Amber Miller, Dean of Science for the Faculty of Arts and Sciences
Within the next decade, these changes will bring about revolutionary breakthroughs in science that will have significant impacts on humanity. Chemistry is becoming more computational and converging with engineering and commerce to design powerful new materials that could change the future of energy and medicine. Biology is evolving from a descriptive science to a quantitative one, driven by massive data sets and sophisticated modeling that makes use of tools from chemistry, physics, engineering, and computer science. Physics is on the verge of unlocking the deepest foundations of the universe through increasingly international collaborations focused on designing powerful new instruments and techniques that store and manage data sets of unprecedented size and complexity. Powerful computer models and high-resolution global data sets continue to document climate change and predict its impact. The environmental sciences have become integrally linked to political science, law, economics, and urban planning.

Nanoscience has become the gateway for inventing two-dimensional materials that may replace silicon and unleash the next revolution in electronics. Our new abilities to probe biological systems have enabled researchers to create a motion picture of the brain’s circuitry that heralds a new era in neuroscience and psychology. Scientists are researching mechanical systems that incorporate living cells and that could harness untapped sources of mechanical energy. Biologists are finding the scientific keys to treating previously incurable diseases with the design of novel drugs. Because of new astrophysical technologies, scientists are discovering Earth-size planets that could have atmospheres and other essential ingredients of life, while studies of the Earth reveal the pathways for the emergence of life on this planet and the nature of present-day microbial communities in extreme terrestrial environments—hot, cold, dry, dark, at high pressure far below the surface—that may be common on other planets.

Columbia University has laid the groundwork for decades of expansion through the construction of the Manhattanville campus and the recently completed Northwest Corner Building on the Morningside campus, which is devoted to interdisciplinary research. With expanding facilities, an unusual number of recruitment opportunities due to expected retirements in the science departments, and many areas of science at the brink of new discoveries, the natural sciences are primed to lead Columbia’s expansion with a bold vision for the future.

A STRATEGIC PLAN—WHY NOW?
The study of natural sciences and Columbia University both stand on the brink of significant change. The traditional delineations between scientific disciplines are increasingly blurred. Research is becoming more globally collaborative and more competitive, while new technologies have opened uncharted territories.

Psychology professor Sarah Woolley studies the social conditions and brain structures that underlie our ability to learn to communicate using the voice. Her research focuses on songbirds because, like us, they must learn their vocalizations and have brain systems dedicated to vocal communication.
This plan puts forth a coherent set of new initiatives and programs that capitalize on the timely opportunities for growth now available to us and aims to increase the intellectual depth, interaction, and inventiveness of Columbia science. We lay the groundwork for creating three major new Columbia institutes, each of which builds on Columbia’s existing strengths and the potential for revolutionary advances. We also identify ways that growth in our nine science departments will strengthen and support existing and planned Columbia institutes. We include new strategies for recruiting outstanding faculty, including a new interdisciplinary faculty initiative, as well as establishing new shared facilities that will support research across a wide range of disciplinary and interdisciplinary programs. We plan for a new Columbia Prize Fellows program, akin to the Harvard Society of Fellows, and new programs to improve administrative efficiency and laboratory infrastructure.

Arts and Sciences has new leadership in science that will support and encourage interaction within and between schools and institutes. This comprehensive strategy will enable us to apply resources toward meeting our goals and objectives in science research more effectively. This plan is ambitious and requires a significant resource commitment over ten years. With its targeted investments and carefully developed new programs, it represents much more than an increased budget—this plan capitalizes on our existing strengths and leverages investments to establish true science research leadership in the twenty-first century.

“This key to this plan is that it comes from the faculty, that it represents the goals, needs, and intellectual directions both for our nine individual science departments, and also for the interdisciplinary opportunities that lie on the interfaces between them.”
—David Madigan, Executive Vice President for Arts and Sciences and Dean of the Faculty of Arts and Sciences

The Planning Process

For the first time the natural sciences departments at Columbia University have put forth a unified plan for the future of the basic sciences at the University. This strategic plan is the result of collaboration that began in February 2012 among the nine departments and has invited input from all of the science faculty in Arts and Sciences. The plan was created by and for the faculty of Columbia’s natural sciences, with each department documenting its own individual strengths, needs, and specific priorities. This overall science plan is built on the strategies outlined by each department and designed to meet our collective needs with a comprehensive set of priorities, actions, and measures of success over the next decade.

Our nine natural sciences departments, which comprise 215 faculty, include Astronomy; Biological Sciences; Chemistry; Earth and Environmental Sciences; Ecology, Evolution and Environmental Biology; Mathematics; Physics; Psychology; and Statistics.

Earth and Environmental Science graduate students exploring a volcanic lava tube in Iceland.
Objectives

The Arts and Sciences’ natural sciences departments have identified three primary objectives that will set new directions for science over the next ten years and secure Columbia’s preeminence in science, ranking among the top ten of academic peers worldwide. Our objectives reflect our dedication to producing outstanding science and attracting the most outstanding faculty, as well as maintaining the visibility and quality of our science education for both undergraduate and graduate students at the highest level. We are also committed to transmitting knowledge to the public and ensuring that our research is applied to twenty-first-century problems, from outreach to the local New York City community to the development of technologies with global application.
No top-tier university can fulfill its educational and research missions without outstanding programs in the natural sciences. Columbia University has exceptional faculty who are leaders in a broad range of scientific disciplines, as well as a long tradition of attracting top students into instructional programs. Many of our science departments have been influential research hubs for much of the twentieth century, and continuing to the present day. In the 1920s and ’30s, Columbia was the mecca for genetics research. In the 1950s, the Columbia Physics Department was the best in the world, leading to the discovery of the laser, seminal work in atomic and nuclear physics, and several Nobel Prizes. In the 1980s and 1990s, Have- meyer Hall housed one of the best chemistry departments in the world and was designated a National Historic Chemical Landmark. In the first decade of the twenty-first century, Columbia has become the preeminent institution for research addressing what could be our greatest modern problem: climate change.

The sciences now encompass a wider intellectual territory than ever before; thus maintaining excellence requires a larger faculty with a wider range of capabilities and skills. In order to uphold Columbia’s tradition of distinction and to successfully address the biggest scientific questions and problems of our time, the natural science departments need to continue to attract and retain outstanding researchers and to ensure that we have critical mass in key disciplines and interdisciplinary areas. The recruiting plan will also strengthen links with the Medical Center and enhance University-wide efforts, such as the Columbia Stem Cell Initiative (CSCI), the Herbert Irving Comprehensive Cancer Center (HICCC), the Columbia Initiative in Systems Biology (CISB), the Earth Institute, the new Institute for Data Sciences and Engineering, and the Mortimer B. Zuckerman Mind Brain Behavior Institute.

Because excellence attracts excellence, crucial faculty recruitments and retentions become easier, less costly, and less time-consuming as Columbia increasingly becomes known both for outstanding research and for supporting research through its available facilities, administrative support, and opportunities to collaborate. The excellence of our faculty will contribute to successful recruitment of the best students, as will the increased support we provide in the form of research spaces and equipment and University-wide programs to enhance research opportunities.
Objective II
To increase the role research plays in educating undergraduate students and to increase research opportunities for graduate students

A central mission of the University is to educate undergraduate and graduate students. Studying science equips undergraduates with the skills to approach and solve problems critically and rigorously. Columbia undergraduates benefit from the best possible classical education, a curriculum that has endured and will continue to be relevant throughout the ages. Giving our undergraduates the opportunity to participate in rigorous and world-class science research complements the time-tested Core Curriculum with a set of tools that prepares students for another mode of critical thinking—the scientific method. Science is becoming increasingly relevant to many of our students’ potential career paths. Training and skills in quantitative reasoning open more doors to college graduates in the age of information than ever before. More entrepreneurial opportunities are made available to graduates with scientific training and quantitative skills than those without. Entire economic sectors based on science are expanding, making jobs available to students with all levels of background in science—from general familiarity to highly specialized skills. With some of the world’s best scientists on our faculty, it is essential that we allow our students the maximum exposure to the research under way on our campuses.

PhD students are the lifeblood of any top-tier science research program. They are the engines of innovation in their departments as they push the boundaries of science and envision its future. Increasing the role research plays in undergraduate education and providing additional research opportunities for graduate students are essential to fulfilling the natural sciences’ mission. While this strategic plan is intended explicitly to address science research, the actions we will take to achieve our objectives will directly benefit and create exciting opportunities for both undergraduate and graduate students at Columbia. Every element of the strategy detailed in this plan directly benefits education, as it must, in order for our plan to be fully effective.

Objective III
To contribute solutions to today’s problems through the dissemination and application of new discoveries

We have seen throughout history how the acquisition of foundational knowledge—pursued for its own sake—has become the basis for technologies that dramatically improve human lives. Through enhancing science at Columbia, we will gain a new understanding that will add to richer thinking about the great challenges faced by humankind today—ensuring adequate supplies of energy, water, and food while maintaining human and environmental health. Solutions to many of these problems will in large part be found through groundbreaking scientific research and interdisciplinary collaboration between our science, engineering, and medical disciplines. As scientists, it is not only our objective to discover these solutions, but our responsibility to effectively disseminate our findings to the public, business community, and leaders. We recognize that a well-informed public is an essential element of a thriving democracy and that applying new discoveries will drive the next phase of the global economy. The research we generate becomes available to the public in a number of ways, from making new curriculum available to partner elementary and secondary schools to the dissemination of new findings through faculty-generated blogs, media appearances, and twitter feeds. Already Columbia sciences play a vital role in New York’s economy through inventions, new enterprise, and substantial licenses and patents. Much of the research driving this economic activity is also changing our lives, forming the basis for new electronics, security applications, medical diagnostics, gene therapies, and technologies for alternative energy generation.
This plan puts forth a coherent set of initiatives and programs aimed at further increasing the intellectual depth, interaction, and impact of Columbia science. The strategy consists of five components, each of which will be implemented through carefully designed new initiatives for research and will be measured for success against metrics identified in this plan. We will achieve our major objectives through: (1) emphasizing cutting-edge research themes and supporting targeted research areas, (2) increasing faculty size, (3) maintaining and increasing faculty quality, (4) investing in shared research facilities, and (5) strengthening our existing research centers and institutes, and supporting new ones.
INTELLECTUAL DIRECTIONS
SIX RESEARCH THEMES

This plan identifies six major research themes that reflect common areas of investigation with exciting promise at Columbia. Three of these themes identify key areas in which existing strengths at Columbia can be leveraged to develop world-leading centers of excellence and lay the groundwork for new Columbia institutes led by Arts and Sciences. The second three themes provide opportunities for growth in new directions that draw Arts and Sciences into important collaborations with three major existing Columbia initiatives.
ARTS AND SCIENCES-LED INITIATIVES
These first three themes encompass new directions and elucidate topics that run through and unify our departments. These areas are chosen based on Columbia’s existing strengths and the potential for revolutionary breakthroughs in the next decade that will have major significance to humanity. We propose allowing institutes for each of these themes to develop organically, guided by faculty interests and scientific discoveries.
Molecular Architectures: from atoms to devices

Materials—be they metals, minerals, polymers, or plastics—are the building blocks of our future. They are the basis for entire industries and countless modern innovations, and they underpin our ability to explore space and the ocean depths. With the advent of nanoscience, researchers have begun to examine and build materials one atom and one molecule at a time. This allows researchers to probe the fundamental nature of matter and to use that information to invent materials with unprecedented and predictable characteristics.

One important nanoscale problem our chemists, physicists, and engineers are trying to solve is how best to replace silicon, enabling us to make even smaller semiconductors. At stake is the continued progress of the electronic and information-processing revolution. One of the promising carbon-based materials is atom-thick graphene, which not only is the strongest material ever discovered but also possesses remarkable electrical properties.

In addition to fabricating materials, researchers are inventing new medical devices and finding better ways to harness alternative energy sources. For example, single-molecule biosensors that run a current through a one-dimensional wire embedded with a strand of DNA can quickly diagnose diseases in the field (such as trachoma, a major cause of blindness in Africa) or detect biological weapons. Foreshadowing exciting advances in alternative energy, a new technique has just demonstrated the capability of transforming a single photon into two electrons. With the right engineering solutions, solar energy efficiency could be pushed well past the current threshold of 35 percent conversion of solar energy into electricity.

The potential for life-changing science and technology emerging from work on the nanoscale is enormous. Given Columbia’s substantial existing strength in this field, investments in this area will accelerate Columbia’s programs to the forefront of the next generation of exciting discoveries.

Life: from proteins to populations

There is scientific truth in the adage that we are all connected through the web of life. And now, new interdisciplinary research methods and new technologies have positioned us for breakthroughs in understanding that web—spanning from the function of a single cell to the remarkable complexity of an ecosystem.

An important example of that intellectual intersection lies in human biology. By applying tools provided by chemistry, physics, engineering, and computer science, biologists are now developing the means to control, with drugs, proteins that were previously viewed as inaccessible. Understanding and controlling these proteins promises the potential to treat previously incurable diseases.

Similarly, biologists studying natural systems are now fusing their research with the work of engineers and physicists to explore new frontiers in energy research. For example, the mechanical energy produced during evaporation by a particular spore may represent a completely new form of harnessable alternative energy.

Technological advances underpin these and other pioneering research pathways. For example, the new observational power of high-intensity lasers makes it possible for neuroscientists to examine the operation of the brain in real time. This opens the door to understanding the rules that make the brain’s trillions of electrochemical events work together to produce human thoughts, emotions, and actions.

Researchers are examining the complex interactions between populations and their immediate environments. They are, for instance, studying how social and economic factors, land-use development, ecology, and climate shifts are interacting to change fire patterns in the Peruvian Amazon. Such changes in this and other regions are leading to large, destructive fires, and insights obtained from this research will help in the formulation of agricultural, land use, and development policies that protect life, property, and local ecologies.

Columbia researchers are also trying to understand the extraordinary chemical complexity of the oceans and what causes them to absorb one-third of the atmosphere’s carbon dioxide—a global process critical to our planet’s climate stability. Microscopic life forms control the biogeochemical balance in the surface ocean, but how they do it—and in turn help regulate the atmosphere’s concentration of carbon dioxide—is unclear. This theme brings researchers from wide-ranging fields together and significantly expands the potential for understanding how microscopic and large-scale processes impact one another, progress that will be critical to solving many of the central problems facing society today.
Columbia scientists played a considerable role in discovering the Higgs boson—the only elementary particle predicted by the Standard Model of particle physics that, until July 2012, had not been found. This recent discovery explains the existence of mass in the universe and brings us a step closer to understanding the underlying makeup of the universe.

Within a decade, scientists will likely observe signatures from the universe dating from when it was much less than one second old, revealing important clues about what caused the Big Bang. Research on the early universe will in turn inform efforts by theoretical physicists and mathematicians striving to uncover the mathematical nature of space and time.

Scientists are conducting experiments both in outer space and in deep, underground mines in order to detect dark matter particles. Their research is close to answering one of the most alluring questions in astrophysics—what is dark matter? They are also employing powerful new astronomical surveying tools designed to reveal the nature of dark energy—another great mystery whose resolution holds clues to the nature of gravity and the ultimate fate of the universe.

Researchers are on the brink of answering some of humankind’s most fundamental questions about our origins and uniqueness within the universe. What makes the expansion of the universe accelerate? How did the Milky Way and other galaxies form? How did life on Earth emerge? Meanwhile, in anticipation of discovering hundreds of Earth-size planets in other solar systems that could potentially sustain intelligent life, astrophysicists are exploring how planets form and are developing techniques to determine which planets have atmospheres and other conditions for life.

This theme facilitates substantial growth in interaction between theorists and experimentalists working across an increasingly broad range of fields, bringing Columbia to the forefront of research on these mind-expanding topics.

**Origins: from the birth of the universe to the beginning of life**

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**EXISTING INITIATIVES**

Currently, Arts and Sciences is integrally involved in three of Columbia’s signature initiatives—the Mortimer B. Zuckerman Mind Brain Behavior Institute, the Institute for Data Sciences and Engineering, and the Earth Institute. The natural sciences will both strengthen and be strengthened by these existing programs, and our faculty recognize clear benefit in the cross-disciplinary collaboration and the opportunities provided for maximizing resources.
**Mind Brain Behavior**

The human brain is arguably the most complex biological structure on the planet. The study of the mind has moved beyond molecular analysis toward investigating ensembles of neurons whose concerted actions underlie the complexity of human thought and behavior. Neural circuits must, in some way, account for high-level functions such as memory, self-awareness, language, joy, depression, and anger. By establishing the Mortimer B. Zuckerman Mind Brain Behavior Institute, under the leadership of the Neuroscience Department of Columbia University Medical Center, Columbia is expanding the realm of traditional neuroscience to encompass other fields within the natural sciences.

Current research in Arts and Sciences includes psychologists looking at the intersection between learning, memory, and decision-making by studying the impact that past experience and explicit knowledge have on one’s decisions and by examining how perception in the brain is accomplished during social communication.

Through its new Grossman Center for Statistics of Mind, the Statistics Department will partner with the Zuckerman Institute. Statisticians are helping answer some of the fundamental questions in neuroscience. Given an input stimulus (a movement, thought, etc.), what is the conditional probability of a neural response? With a finite number of possible inputs, statistics can help decipher the neural codebook.

As the Zuckerman Institute continues to develop, Arts and Sciences will play an increasingly essential role in connecting traditional neuroscientists with their colleagues in these and other natural sciences.

**Data Sciences**

Living in the Information Age, we are confronted with unprecedented access to the breadth of humanity’s knowledge. The world’s incredible connectivity is fueled by our ever-faster computing power, which yields ever-larger amounts of data. The field of data science has emerged to extract meaning from and efficiently handle that data.

The University’s recent launch of the Institute for Data Sciences and Engineering (IDSE)—an interdisciplinary endeavor led by The Fu Foundation School of Engineering and Applied Science that will address the immense challenges and opportunities posed by our data-rich society—offers significant opportunities for collaboration with Arts and Sciences. The natural sciences will play an important role in at least four of the five new IDSE centers. The Smart Cities Center will incorporate research by the Departments of Earth and Environmental Sciences and Ecology, Evolution and Environmental Biology, and, potentially, Psychology. The Health Analytics Center will include collaboration with the Departments of Chemistry and Biological Sciences. And the Financial Analytics Center will cover topics significant to the joint financial engineering degree, in which Math Department faculty will play a significant role. Finally, the Center on the Foundations of Data Science will draw on the expertise of faculty in a broad range of fields—statistics, math, physics, and others.

The explosion in computational power, and in instrumentation for data collection, impacts all areas of science. No research university can hope to achieve and maintain a preeminent position in science without strong collaboration between statisticians and data scientists and a wide array of data-rich fields. The development of the Institute for Data Sciences and Engineering, working in close collaboration with Arts and Sciences, is timely and has great potential for positioning Columbia at the forefront of this important direction of research.
Our planet and its inhabitants face great challenges in the twenty-first century. By 2050, nine billion people—many of whom will struggle in deep poverty—will vie for Earth’s finite resources, just as the full impact of climate change begins to take effect. Columbia’s Earth Institute, including the world-leading Lamont-Doherty Earth Observatory, works to help guide the world onto a path toward sustainability through research in public health, poverty, energy, ecosystems, climate, natural hazards, and urbanization. The Earth Institute, like Columbia’s other existing institutes, is made up of faculty from Arts and Sciences and other Columbia schools, drawing together great research from multiple disciplines to create better solutions to today’s problems.

Columbia’s Climate and Life Initiative responds to these urgent challenges with a broad-based commitment of our intellectual resources to understand how climate change will affect humanity’s access to food, water, shelter, and energy in the decades ahead. This initiative will focus research on the impacts of climate change that are most relevant for human sustainability. More severe heat waves, droughts, and floods—extreme weather, rising seas—will have rapid and dramatic effects on ecosystems, crop yields, water resources, and coastal infrastructure. It is essential to quantify the probability of likely impacts, collectively known as the “social cost of carbon.” In parallel with this effort, our scientists and engineers will also focus on techniques, such as carbon capture and storage, to mitigate these impacts by reducing greenhouse gas emissions in an economically viable way. Additionally, we must study ecological and evolutionary patterns and processes to understand life, sustain biodiversity, stabilize population dynamics, and ensure functioning ecosystems in natural and human-modified systems. We seek to meet the challenge of this giant, multidisciplinary effort.

Arts and Sciences research, with its strong foundations in fundamental Earth science and ecosystem investigation, will be broadened and enriched by new collaborations with other Columbia faculties. Advances in genomics research in biological and medical sciences at Columbia are used to study cellular-level responses to ocean acidification and the effects of biodiversity loss on populations. Nanoscale imaging of reactive surfaces holds the key to maximizing chemical carbonation rates, for permanent storage of CO₂ in inert, nontoxic minerals. Other synergies at the University include research on environmental decision-making and how social psychology can inform our understanding of our interactions with our environment. Our scientists are developing better ways to understand, combat, and adapt to climate change, protect our oceans and other ecosystems, advance alternative energy sources, and sequester carbon. As dense populations settle along coastlines, riverbanks, and steep slopes, we will continue to develop methods to predict the risks posed by earthquakes, landslides, major storms, and tsunamis. Studies of Earth use the tools of statistics and data analysis extensively, and our investments in this area further reinforce strong ties to the research conducted through the IDSE.

This theme, a primary aspiration of many of our students, is driven by the need for effective stewardship of the planet and for creating sustainable communities based on renewable resources.
**Targeted Research Areas**

Many of the world’s modern challenges require solutions that cut across the traditional disciplines on which our departmental structure has been built. These interdisciplinary collaborations rest on the strong disciplinary foundations that our scientists build in their respective fields.

While the themes and opportunities above highlight overarching issues that can be addressed jointly by many of our science departments, we are equally invested in targeted research within each discipline. Creating pillars of excellence in particular subfields can set our science departments apart from their peers and allow us to build unique strengths. This plan prioritizes investments in critical subdisciplines within departments, referred to as targeted research areas. These areas will be built up at the departmental level, as set forth in the departments’ specific strategic plans. Investing in and building targeted research areas is a critical component of the strategy to bring science departments into greater prominence among universities doing the best science research. Each department has identified and justified its most important targeted research areas for its future. Some growth in targeted research areas will be facilitated by the creation of new centers, and some of it will be growth within a particular department. Focused research goals will be achieved through strategic hiring practices such as targeted recruitments and cluster searches, as well as by fostering good departmental planning in order to build or maintain sufficiently large faculties to achieve and maintain preeminence in critical subfields. The research areas are not repeated here, but will be implemented as essential components of this plan.

Columbia’s best asset for determining new directions in scientific research is its faculty. The six broad research themes and multiple targeted research areas within disciplines will evolve with faculty-determined directions.

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**Measures of Success**

- New, large, interdisciplinary-sponsored research projects and links with other schools
- Faculty recruitments and retentions that rely on investment in centers and institutes built around these themes
- Outstanding new interdisciplinary appointments
- Fundraising success endowing centers
- Demonstrated success recruiting the best rising-star junior faculty
- Demonstrated success attracting outstanding well-established luminaries
- Improved track record of recruiting outstanding graduate students to work in specific subfields, and positive trends in the career trajectories of undergraduate and graduate students
- Improved departmental rankings

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A worm with several neurons illuminated by green fluorescent protein (GFP), a now widespread technique for labeling living cells developed by Biological Sciences professor Marty Chalfie, for which he won the Nobel Prize in 2008.
Faculty and Research

Faculty Size

Faculty size directly impacts the breadth and quality of our research product. While departments can produce outstanding research with small faculty sizes—as several of our departments have demonstrated—a larger faculty allows for a greater range of expertise as well as greater strengths in specific areas. Maintaining critical mass in key subfields and interdisciplinary endeavors enables productive scientific collaboration and guards against crisis when a faculty member retires or leaves the University. Each faculty member is an essential mentor to students, and increasing the faculty size serves our student population with more top-notch mentors covering a broader range of research interests.

Several of the science departments urgently need additional faculty in order to handle their educational responsibilities and/or to cover the important research areas within their fields. Other science departments are better represented and now must maintain their current sizes in order to preserve their strengths. This plan identifies the departments most in need of growth while recognizing the importance of maintaining the strength in our larger departments through replacement hires and taking advantage of outstanding “target of opportunity” hires as they arise.

Measures of Success

- Significant growth in areas targeted for short-term expansion in first five-year period
- Successful growth in all targeted areas by end of approximately ten-year period
- Improved departmental rankings
- Successful retention of outstanding faculty

Mathematics professor Igor Krichever teaching Calculus IV. Photo courtesy of Mathematics doctoral student Nava Balsam.
An outstanding faculty is the engine behind world class research. Existing top faculty, high-quality shared research facilities, excellent administrative support structures, and a collaborative environment will make it possible for our departments to continue to attract leading figures and rising academic stars. Many researchers are drawn to an institution based on opportunities for collaboration and the reputation of the departments that they will join. As our faculty quality becomes recognized in more research areas, the University will increasingly become a magnet for faculty and students throughout the world.

Due to retirements and department growth, roughly 40 percent of the natural sciences faculty will be new hires within the next decade. This presents a challenging but exciting opportunity to attract the next generation of scientific leaders to Columbia. We plan to leverage current and future investments in new University initiatives and facilities to recruit and retain the best faculty at all levels across departments. We also have a time-sensitive chance to leverage new laboratory space for the best possible recruitments—this new space has become available in the Northwest Corner Building and will soon become available in the Jerome L. Greene Science Center, slated for completion in 2016. We will also modernize spaces in our historic buildings in order to make them appropriate for cutting-edge research so we may better attract and retain outstanding faculty. Over the course of this plan, we expect that additional spaces on the Morningside campus will be made available as the Manhattanville campus expands and thrives—most notably in Uris Hall, an ideal central location for some of our science departments and interdisciplinary activities.

In an effort to be more strategic about recruitments, we will strongly encourage all natural science departments to adopt best hiring practices. For example, departments may find it beneficial to prioritize subfields with the intention of filling these positions over the course of several years. By agreeing to look for the best candidates across multiple different subfields over an extended period of time, we maximize our potential to attract the top minds when they become available for hire. Another example is to cluster hires at times that present a unique opportunity to build up a high-priority research area identified in a department’s strategic plan or to otherwise gain preeminence in an exciting new interdisciplinary area.

**FACULTY QUALITY**

An outstanding faculty is the engine behind world class research. Existing top faculty, high-quality shared research facilities, excellent administrative support structures, and a collaborative environment will make it possible for our departments to continue to attract leading figures and rising academic stars. Many researchers are drawn to an institution based on opportunities for collaboration and the reputation of the departments that they will join. As our faculty quality becomes recognized in more research areas, the University will increasingly become a magnet for faculty and students throughout the world.

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**Measures of Success**

- Increased number of faculty recognized by top scientific awards and honors (e.g., Nobel Prizes, members of the National Academy, American Academy)
- Improved departmental rankings
- Improved track record of recruiting outstanding graduate students and positive career trends identified in trajectories of undergraduate and graduate students
- Demonstrated success recruiting the best rising star junior faculty
- Demonstrated success attracting outstanding well-established luminaries

Chemistry professor Virginia Cornish, whose work uses biological systems to synthesize and evolve chemical diversity through chemical synthesis and DNA technology, working in her lab with a graduate student.
Providing faculty and researchers with state-of-the-art facilities that enable them to conduct research at the highest levels made possible by today’s technology is essential to maintaining top-quality competitive research. With better laboratories, collaboration spaces, and equipment, we will also be able to provide better training opportunities to undergraduate and graduate students and postdoctoral scholars.

This strategic plan prioritizes targeted investments in both new and renovated facilities to support research with an emphasis on cost-effective and efficient use of available space. The majority of these investments support shared facilities that are designed to serve the various needs of many researchers. When prioritizing investments, we will consider which facilities and equipment can easily and cost effectively take advantage of local opportunities so that we can avoid duplicating major investments. Our recent partnership with the New York Genome Center exemplifies this approach, allowing faculty access to a consortium of highly advanced genome sequencing capabilities with a membership fee and user fees. Shared research computing and cloud computing is an opportunity for shared investment in collective resources on or off campus. This strategic plan also prioritizes faculty-led decision making. The Shared Research Computing Policy Advisory (SRCPA) Committee, a faculty group charged with determining the best investment strategy to address computing needs for researchers across departments and schools, and the Shared Facilities Task Force, convened to study the best way to invest resources earmarked for nanoscience, serve as a models for the way in which resource decisions will be made going forward.

**Measures of Success**

- Outstanding recruitments and retentions made possible by new spaces in the Northwest Corner Building and the Jerome L. Greene Science Center
- New shared research facilities consistent with key research themes and specific research areas
- Outstanding recruitments and retentions made possible by modernized spaces and necessary investments in the laboratory facilities in Havemeyer, Chandler, Fairchild, Pupin, Schermerhorn, and Northwest Corner, as well as other research buildings
- Key shared facilities to support new centers and institutes and enhance research competitiveness
- Improved departmental spaces, including shared spaces for theoretical and computational work, interactive spaces for graduate students, and new laboratories

The multiple follicle stem cell lineages in a *Drosophila* ovary are revealed by different combinations of fluorescent proteins. Biological Sciences professor Daniel Kalderon is studying how communication between cells, including stem cells, regulates their behavior.
This plan supports the ongoing role of departments as autonomous academic units responsible for hiring, promoting, and retaining faculty and determining the intellectual direction of disciplinary and subdisciplinary pursuits. Simultaneously, it supports strengthening existing Columbia institutes and centers as well as laying the groundwork for the eventual creation of three new Arts and Sciences–led institutes comprised of constituent centers.

Centers and institutes provide the infrastructure necessary to foster collaboration between faculty, students, and researchers across disciplinary boundaries, providing the administrative support required to facilitate large, multi-PI research proposals and administering those grants in a cost-effective and efficient way. Staff support in centers and institutes will also be crucial for sustaining shared research facilities and helping faculty meet increasingly time-consuming compliance requirements. It is essential that we do everything possible to alleviate those burdens. Staff time should be made available to assist faculty with compliance requirements, including increased federal regulations and environmental health and safety mandates. It will also be crucial to develop administrative support for interdisciplinary partnerships across schools, among departments, and within departments.

The proposed centers and potential institutes will bring researchers together to tackle important new ideas and ensure that there is a critical range of expertise to forge innovative areas of research. The centers and institutes will provide support for outstanding visiting scholars and create a rich and interactive environment for undergraduates and graduate students. They will provide essential support for new shared facilities and the administrative structure required to apply for and ultimately administer large center grants.

One of the most important priorities of the University over the past decade has been the planning and building of the new Northwest Corner Building on the corner of Broadway and 120th Street. The building, linked to the adjacent Chandler and Pupin Halls, provides the high-quality research space required to nurture the constituent centers based around the two interlinking themes: Life and Molecular Architectures. These themes are aligned with faculty research across schools and allow faculty in the building to interact closely with colleagues from the School of Engineering, who will also play key roles in these Arts and Sciences–led institutes.

Columbia’s executive vice president for research is working with Arts and Sciences, the Engineering School, and Columbia University Medical Center to understand these units’ individual strategic plans in order to develop an overarching strategy for advancing research at the University. The Arts and Sciences strategic plan focuses on the particular strengths, opportunities, and areas of need in the nine science departments, but we will also take advantage of opportunities that may arise within and outside of Columbia University. The overall plan for research at Columbia, formulated by the executive vice president for research, will be built from the priorities and vision laid out in this document and the respective strategic plans of the Medical Center and the School of Engineering.

**Measures of Success**

- Endow founding centers to seed the three new Arts and Sciences–led institutes
- Demonstrate improved faculty experience compliance and environmental health and safety requirements (as judged by faculty feedback through departmental chairs)
- Demonstrate sustainable model, including endowment support, user fees, etc., to support shared facilities
- Demonstrate increased volume of large center grants from federal funding agencies and/or foundations
- Demonstrate additional joint investments with other Columbia schools, centers, and initiatives
- Make outstanding joint recruitments within Arts and Sciences and with other University units

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Chemistry professor Ann McDermott in her laboratory with students and postdocs. Her research focuses on new spectroscopic techniques to document the structure and dynamics of proteins, including proteins that are responsible for conveying messages in biological systems.
**IMPACT**

For more than a century, the fundamental scientific research carried out in the nine natural science departments has been a driving force behind a basic understanding of ourselves and the world. This plan recognizes that fact and supports our departments’ intellectual endeavors in curiosity-driven research in pursuit of scientific excellence. At the same time, the foundational discoveries emerging from research laboratories are built upon and used in more ways than can be enumerated.

Things we take for granted in everyday life, and advanced life-saving technologies that we view as near miracles, are all made possible by the understanding built in the basic laboratories of the chemist, biologist, geologist, physicist, mathematician, and their science colleagues. We therefore also emphasize the impact that increasing scientific excellence at Columbia will have on our students, our University broadly speaking, our community, our economy, and our world.

We have seen throughout history how the acquisition of such foundational knowledge—pursued for the sake of knowing more—has become the basis for technologies that dramatically improve the human condition. While many of our scientific discoveries do yield outstanding and frequently unexpected applications, our science research is valuable in adding expertise to the encyclopedia of human thought and for the pursuit of knowledge itself.
Achieve Preeminence in Science Research

The strategies outlined in this plan will help assure Columbia’s place among the top ten, and in many cases top five, universities in all fields of the natural sciences.

Enhance Research Competitiveness

It is becoming increasingly competitive to obtain the federal funding that supports the majority of scientific research. More investigators are competing for fewer available research dollars, making it essential that Columbia develop strategies to increase our competitiveness, to ensure that our investigators successfully obtain the research funding required to keep the best science at Columbia, and to bring in the overhead funding on which the University relies. Given the natural science departments’ relatively small size and outstanding faculty, we currently compete well for individual grants but lag behind our peers in obtaining large center grants. With larger numbers of stronger faculty, outstanding postdocs and students, excellent staff support, modern laboratories, a strong collaborative environment, and the sophisticated shared research facilities outlined in this plan, we will develop precisely the ingredients required to successfully compete for research funding both at the individual investigator level and at the multi-investigator level required to support center grant applications.
Increase Research Opportunities for Undergraduates

This plan supports collaboration with Columbia College to raise support for 100 new undergraduate research fellowships each year. Beyond direct support for students, this plan also makes huge strides toward increasing undergraduates’ access to science faculty and research facilities, improving their research experience. Every shared research laboratory and center developed as part of this plan will be a place where undergraduates will learn sophisticated new research techniques, interact with other students, faculty, and visitors, and develop important skills.

Increasing faculty size and quality will provide additional outstanding graduate advisers and research mentors covering a wider range of disciplines for our undergraduate students, enabling more of them to take part in cutting-edge research as part of their education. A larger faculty representing a wider range of expertise also enables Columbia to offer additional elective science courses and specialty seminars, enriches the perspective from which our faculty teach our science courses, and reduces class size.

Improving university research facilities has a direct and important impact on our ability to provide a first-rate research experience for students. For example, with facilities such as a shared state-of-the-art nanofabrication laboratory, a research greenhouse, and access to a large facility telescope, students can gain firsthand experience with the cutting-edge tools and techniques of the most advanced research in a given field, preparing them for graduate study. It is essential that Columbia students have the best access to resources in their chosen fields of study—facilities for characterizing synthetic biomolecules, imaging nanotubes within natural crystals, and analyzing the genetic makeup of living systems. This will enable stronger graduate theses and prepare students for a wide range of other exciting career options.

Our plans to develop better collaboration, management, and partnerships across the University will enable increased interdisciplinary and interschool projects for undergraduates, potential new degree programs for master’s- and PhD-level students, and a richer experience for all of our students. An exciting example is the current cooperation between mathematics and statistics on the education and training of “quants,” experts in the technical tools of modern financial analysis. By improving support systems to manage student placement in laboratories and identifying additional funding sources for research internships, we can take better advantage of talent and serve students with an enriched training and educational experience.

Improving University research facilities has a direct and important impact on our ability to provide a first-rate research experience for students.
**INCREASE DIVERSITY**

This plan recognizes the fundamental importance of expanding the pipeline for a more diverse population of scientists in the next generation. The Bridge to PhD Program has been enormously successful in enhancing the participation of students from underrepresented groups in PhD programs in the natural sciences. We will help support this successful program and develop undergraduate research fellowships, graduate PhD fellowships, and a postdoctoral fellows program—all of which will be outstanding opportunities to attract a broad, diverse group of developing scholars to Columbia. The new interdisciplinary hires program represents another opportunity to bring talent from diverse backgrounds to Columbia at the faculty level. Roughly 40 percent of the science faculty will be new to Columbia by the end of the ten-year time frame of this strategic plan. This further increases our current opportunity to enhance the diversity of our faculty.

**STRENGTHEN SYNERGISTIC RELATIONSHIPS WITH OTHER FIELDS**

Strong science at Columbia provides a foundation for good decisions—legal, commercial, political, economic, and ethical—while strong social science and humanities departments and professional schools provide a key framework for integrating new scientific discoveries and inventions into the life of the University, the community, and the world. These synergies will not only strengthen non-science fields at Columbia, but this plan also supports collaborations between campuses. For example, advances in genomics research in the biological and medical sciences can be used to study cellular-level responses to ocean acidification and the effects of biodiversity loss on populations. Other collaborations include researching environmental decision making and examining human interactions with the environment through the lens of social psychology. With Columbia’s core strength in the humanities and an impressive array of top-notch professional schools, this opportunity to bolster science research will strengthen our ability to discover key new insights into the natural world, invent new technologies that will change the world, and meaningfully debate the ethical, legal, political, and economic possibilities and responsibilities that come with the power of being on the cutting edge.

_The EBEX experiment, led at Columbia by Physics professor and dean of science Amber Miller, about to be launched into the stratosphere from the long-duration balloon base in Antarctica. EBEX is designed to measure the intensity and polarization of cosmic background radiation._

_Enhance Public Outreach and Education_

Our faculty and researchers are actively engaged in educating the public about science. This plan enables them to continue and expand their activities in public outreach, including teacher training, enriching K–12 curriculum with better science, media engagement, and multiple other applications. When major global phenomena occur—such as Japan’s earthquake, tsunami, and ensuing nuclear disaster—Columbia faculty are in the news explaining what happened and how. Our faculty lead and participate in programming for wide audiences on television programs such as _NOVA_ and _Charlie Rose_, and have founded exciting outreach events like the World Science Festival. Ongoing events such as biweekly stargazing nights from the top of Columbia’s Pupin Hall and “sidewalk astronomy” programs, which take telescopes to the streets of Manhattan and Harlem, reach hundreds and sometimes thousands of New Yorkers. We play an important role in New York City’s culture, broadening it with the rich knowledge and education provided by our faculty.
Each year, on average, Columbia Technology Ventures (CTV) manages approximately 300 new inventions from Columbia inventors, executes 50 to 70 license agreements, launches 15 new companies, and generates more than $135 million in gross licensing revenues.
Columbia University has an exceptional record of transferring technology to commercial applications. Each year, on average, Columbia Technology Ventures (CTV) manages approximately 300 new inventions from Columbia inventors, executes 50 to 70 license agreements, launches 15 new companies, and generates in excess of $135 million in gross licensing revenues. It is also in close proximity to and collaborates with IBM and the Brookhaven National Laboratory. Centers within both the Molecular Architecture and the Life Institutes will have enormous potential for technology transfer and commercial partnerships. The ongoing research and rich interactive environment within these centers will naturally lend itself to potential practical applications that drive commercial ventures, as well as fundamental discoveries.

Contribute Solutions to Today’s Problems

Natural sciences faculty contribute significantly toward helping policy makers understand the challenges and potential facing society and future generations. For example, faculty have participated in the Intergovernmental Panel on Climate Change, national level planning for conservation, and local efforts in New York for achieving sustainability goals. Our science faculty are leaders in devising the capabilities to predict, potentially mitigate, and recover from the disastrous effects of major weather events such as last year’s Superstorm Sandy and the previous year’s Hurricane Irene. As we discover how to manufacture and utilize novel materials, we get closer to effectively harnessing renewable sources of energy on the large scale necessary to stem the uncontrolled release of greenhouse gases into our atmosphere. Science research is responsible for lifesaving technologies and new knowledge that will ultimately improve life on our planet, but it also underpins technology that we enjoy on a daily basis. New electronic materials developed by scientific research, will continue to revolutionize our lives, as they have recently through computers and smartphones and did centuries ago with the discovery of electricity and the development of steam engines.
Specific Actions, Timeline, and Resources

This section of the plan identifies the concrete steps we plan to take in support of an overall strategy of maintaining and enhancing excellence in the sciences and positioning the nine science departments to compete with the top ten of peers globally.

The past decade has seen the successful expansion of the Departments of Mathematics and Statistics and the creation of an entirely new Department of Ecology, Evolution, and Environmental Biology. While these successes have been significant, due to budgetary constraints our laboratory sciences have experienced little or no growth in the past decade, and our laboratory facilities in existing buildings have not been modernized in many decades. A priority will therefore be to grow and revitalize laboratory sciences while ensuring that our nonlaboratory science departments retain the support required to continue to excel. Departmental growth will result from concerted decisions to strengthen existing focus areas within a discipline, or from an identified need to build in a new direction. These priorities are set by departments in their individual strategic plans and will be revisited as the plan is implemented to ensure long-term effectiveness given changing conditions. In order to implement innovative change that responds to the needs of the sciences and looks forward to a coming generation of extraordinary excellence at Columbia, we have identified a set of strategic initiatives that will meet our overarching goals.
Institutes, Centers, and Shared Facilities

For each of our new key overarching research themes outlined above, we anticipate the eventual creation of a new Columbia institute. In order to most effectively identify the key constituent centers that will make up each institute, we plan to provide seed investments to begin centers in promising areas within each theme. We will then work to endow several of these “founding centers” over the next decade. These endowments will be used to help staff shared facilities, hire administrative support to enable effective submission and administration of large center grants, support visiting scholars, and meet other needs for enriching thematic research. Key shared facilities described below are associated with each of the three themes, providing the research tools required to support the most innovative research; provide collaborative opportunities between departments and schools; bring together faculty, students, researchers, and visiting scholars to tackle the most difficult problems; give Columbia the competitive edge in the contest for federal and foundation funding; and provide research opportunities for Columbia undergraduates.

With resource allocations identified below, Arts and Sciences will seed the founding centers in the three major research themes not already represented by a world-class institute at the University. Four of these centers have already been identified: the Columbia Nanoscience Center representing Molecular Architectures; the Center for Advanced Biological Imaging, in the Life theme; the Center for Theoretical Physics, in Origins; and later, the Center for Galactic Origins.

This photo of coral sampling was taken by Braddock K. Linsley, a Lamont research professor who studies the use of massive coral skeletons for paleoclimatic reconstruction.
INTERDISCIPLINARY HIERES PROGRAM
We plan to begin a program designed to support and encourage interdisciplinary hires between our departments. New faculty lines will be awarded to the most promising candidates chosen each year through a competitive process requiring that at least two departments support the hire and a joint appointment. We will consider using these resources to identify candidates at the junior and senior levels—alternating each year between junior candidates identified through the regular search cycle and target of opportunity hires that may appear at any time of year.

Pictured on opposite page: The Research icebreaker vessel Nathaniel B. Palmer in Antarctica. The vessel is chartered by the National Science Foundation and used by Columbia environmental researchers. Photo courtesy of Lamont research professor Joaquim Goes.

COLUMBIA PRIZE FELLOWS PROGRAM
Postdoctoral fellowship opportunities vary in prestige, structure, and preparation for gaining tenure-track faculty positions. Many of Columbia’s peer institutions offer named postdoctoral fellowships for which the very best early-career scientists compete every year. These opportunities invariably attract the best recent PhDs. The development of a Columbia Prize Fellows Program, consisting of endowed named fellowships and for which the most talented scientists compete, is critical to the growth and success of the natural sciences at Columbia. Attracting the most talented trainees in the sciences puts our faculty at a competitive advantage in research productivity and strengthens the pipeline for attracting more talented junior faculty.

GRADUATE FELLOWS PROGRAM
Over the period covered by this plan, we intend to endow fellowships for one out of every ten of our PhD students. While endowing fellowships for all of our students is a long-term ambition, the more realistic immediate goal of providing fellowships for a fraction of our students during this ten-year period will have great impact. Endowing a tenth of our graduate students significantly enhances our ability to compete with other universities for the most outstanding students and leverage the federal research dollars awarded to our faculty. As excellent graduate applicants from diverse backgrounds are very often offered competitive fellowships, this program will significantly enhance our competitiveness in attracting a more diverse graduate student body.

UNDERGRADUATE RESEARCH
We will support the development of additional research programs for our undergraduate students with the goal of working with Columbia College to provide opportunities for all students interested in participating in laboratory research, starting with one hundred additional opportunities each summer. We look to the highly successful I. I. Rabi Science Scholars Program as an example of the positive impact that such a program can have on our students. The Science Research Fellows Program in Columbia College is another thriving model for undergraduate research that provides support for research internships while engaging students in weekly seminars and helping them identify research mentors. Individual research programs for undergraduates also exist in specific departments. More than one hundred undergraduates participated in the Summer Undergraduate Research Fellowship (SURF) program in the Department of Biological Sciences last summer. Columbia’s Global Centers are another way for students to participate in fieldwork and for them to experience the type of international collaboration that is becoming the norm in research.

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OTHER CROSS-CUTTING PROGRAMS

We have established a laboratory research support program in which $250k/year is allocated on a competitive basis to enable moderate-size repairs and upgrades to laboratories that were not otherwise covered by any of the existing programs. This strategic plan allocates resources to carry this program forward because of its current success. We also flag support for shared research computing to be allocated by the Shared Research Computing Policy Advisory Committee, in order to provide centralized support to all of our researchers with significant computing needs, generating efficiencies and enabling collaborations. By helping to support the “Bridge to PhD” Program that provides up to two years of full-time, paid research experience and mentoring at Columbia, we will prepare students from underrepresented groups to participate in natural sciences PhD programs.

RESOURCES

This strategy sets a direction and prioritizes actions to be implemented over time. We will have the flexibility to either delay (if resources require) or accelerate (if resources permit) certain actions, but these actions have been prioritized in view of achieving our long-term goals and major objectives over the next ten-year period. There could also be changes in external environments—such as a major research breakthrough or a significant adjustment in federal research funding availability—that would cause us to reexamine our timing or particular prioritization of our goals and actions. We will report on progress and revisions to the plan on a periodic basis as we implement the below-mentioned actions, taking into account internal and external factors that may cause us to adjust, accelerate, postpone, or reexamine the actions we are planning to take in pursuit of the long-term vision.

This is an ambitious strategy with significant resource requirements. Implementing much of this strategy depends directly on the creation of a significant development campaign for science research in Arts and Sciences. It will also require careful budgeting of Arts and Sciences resources as well as support from the central administration and the use of debt capacity for certain capital investments according to the priorities of the strategic plan.

To broaden the prospect pool of science donors beyond alumni, we are working with the Office of Alumni and Development to establish an advisory board for science. We must identify and engage board members and a board chair who will assist Arts and Sciences in broadening the pool of prospective donors interested in funding cutting-edge science research. Fundraising is an integral component of this strategy and will be essential in order to meet the long-term goals within the ten-year time frame.

In conjunction with the establishment of the advisory board for science, Arts and Sciences must develop a detailed plan for a major science campaign over the next ten years. The advisory board will assist in forming this plan and will advise on implementation. The board will also build its own membership during the five-year time frame to bring in additional assistance with goals and advisement on structuring and refining the science development program.
A rendering of the new Center for Theoretical Physics in Pupin Hall.
Near-Term Goals (First Eighteen Months)
The near-term goals emphasize developing structures that will allow us to make smart investments in the medium and long term.

Faculty
While setting the stage for additional investments over the next eighteen months, we prioritize significant growth in only one department, while making strategic hires to replace or anticipate the replacement of large numbers of retirees in three others. This will be implemented with complete recognition of the importance of maintaining size and strength in our other departments:

- **Psychology**, because of numerous imminent retirements, lack of capacity to service undergraduate majors, and inability to properly support the graduate program, is urgently in need of immediate attention. We therefore plan to first direct resources toward growth in Psychology. The developing partnership with the Mind Brain Behavior Initiative will provide an exciting opportunity for growth and collaboration for the Psychology Department and joint recruitments are anticipated. Some new faculty will have laboratories in the Greene Science Center, and we expect that at least a couple of current members of the department will move their laboratories to that new Center as well, allowing space on Morningside to recruit additional faculty.

- **Biological Sciences** must immediately begin to grow and anticipate retirements by hiring in the areas of population genetics to maintain competitiveness with peer institutions in the new era of quantitative and interdisciplinary biology.

- **Physics** needs to begin immediately hiring replacements for recently retired faculty and anticipate coming retirements in the area of theoretical physics, due to the recent retirements of the two Nobel laureates and the urgent need for revitalization in both theoretical and condensed matter/atomic, molecular, and optical (AMO) physics.

- **Chemistry**, due to the imminent retirement of some eminent chemists, must protect and begin to rebuild its areas of strength. This includes hiring new faculty in chemical biology and synthetic/organic chemistry.

- **Mathematics**, which had one of the best Topology groups in the world until 2008, must begin to rebuild that pillar of strength with high-priority recruitments.

Reversal of mutant huntingtin toxicity by microtubule inhibitors: at left, a neuronal cell; at right, a cell treated with a microtubule-inhibiting drug. Photo courtesy of Biological Sciences and Chemistry professor Brent Stockwell.
FACILITIES

The University has already invested in two new buildings for science research—the Northwest Corner Building and the Jerome L. Greene Science Center. These buildings are or will be outfitted with the best labs and equipment available. Additionally, Arts and Sciences has begun a process to invest in upgraded facilities for nanoscale sciences, a major component of the Molecular Architectures research theme. A theory center in Pupin will bring together theoreticians from physics, mathematics, astronomy, and statistics, supporting the Origins theme, and we will provide seed support for the founding center of the Life theme. Other facilities will be dedicated to research in other cross-departmental areas of need, as well as addressing department-specific facilities needs. The most pressing facilities needs, to be addressed within the next eighteen months, are as follows:

Planning Needs

Establish long-term space plans for four departments:

- Astronomy
- Psychology
- Ecology, Evolution, and Environmental Biology
- Statistics

We must identify and outfit space on the Morningside campus to allow these departments to grow, as well as plan feasible long-term space solutions for these departments. The possibility of new space in Uris Hall should play a major role in these long-term plans. These plans will also take into account opportunities for space in Manhattanville, such as in the Jerome L. Greene Science Center, for some departments. Although we expect opportunities for additional research space to result from our partnerships with other University units, the primary focus of long-term space planning will be on the Morningside campus.

Identify temporary space on campus for approximately sixty-five PhD candidates in Mathematics

This space should accommodate the entire group so that they may collaborate and require little renovation or capital investment. Spaces that could accommodate students from other departments as well will be prioritized.

Major Capital Investments for Shared Facilities

Build shared facilities for Molecular Architectures

- Work with the already-established faculty committee to prioritize needs and commit identified funding provided by A&S and SEAS.
- Raise additional funding for shared facilities and related needs in nanoscience.
- Work with Facilities to effectively plan, design, and build shared facilities identified by the faculty committee.

Complete the first half of the Pupin Theory Center

- Complete the design study.
- Secure matching funds for phase II and begin construction for phase I.
- While construction is under way, use the promise of the new facility to recruit outstanding faculty of high priority to the Physics Department, and build stronger collaborations (possibly including joint hires) with the Department of Mathematics, a natural partner in the Theory Center.

Conduct a feasibility study for a research greenhouse

- Work with CU Facilities to complete a feasibility study.
- Raise funding to cover a full design study and the first phase of construction.

Pilot a research initiative in Life theme

- Seed funding for founding center within Life theme.

Fund first steps in shared research computing facilities

- Seed funding for pilot initiative within shared research computing, according to the recommendations of the Shared Research Computing Policy Advisory (SRCPA) Committee.

Necessary Renovations to Maintain State of Good Repair in Science Buildings

Pilot laboratory support program

- Maintain the functionality of research environments by addressing modest day-to-day needs in support of the laboratory infrastructure and systems, such as restoration of existing minor laboratory infrastructure or systems that have fallen into disrepair and make minor modifications of existing infrastructure or systems required in order to enable new research directions.
**Arts and Sciences–Wide Initiatives**

**Establishment of the Columbia Prize Fellows Program**
- Recruit stellar scientists into the pilot program and use their impressive research outputs to fundraise for an ongoing or endowed prize fellowship program.
- Raise endowment for at least one fellowship.

**Administrative support program for research**
- Working with the science department chairs, design and identify resources to be allocated toward a pilot program specifically targeted at assisting faculty with administrative burden in a way that will be most useful to the research mission.

**Interdisciplinary Hires Program**
- Work with a faculty committee to propose details for a pilot program and recruit the first interdisciplinary hire through the program in the eighteen-month time frame. If the pilot is successful, plan for a full implementation of an ongoing program in the five-year time frame.

**Fundraising**

**Establish a fundraising advisory board for science**
For many decades, the federal government has substantially or completely supported the science enterprise at universities. It is becoming increasingly apparent that federal funding will only constitute a portion of funding needed to pursue the best science. In the face of flat or declining federal funding, we must ensure that we position ourselves to be as competitive as possible and win more than a proportional share of federal awards. We also must prioritize raising substantial institutional and philanthropic funds for science, which will also allow us to leverage the investments by the federal government and increase our competitiveness in winning grants.

In close cooperation with and guided by the Office of Alumni and Development, establish an advisory board for science with key individuals whose goal will be to increase private funding for science research in Arts and Sciences. The board will assist the Office of Alumni and Development in broadening the network of prospective donors beyond the current, largely alumni-focused, prospect pool. In the eighteen-month time frame, we expect to have established an inaugural board, whose founding members will assist with additional recruitment to the board as necessary and as opportunities arise.
In the medium term, we prioritize the growth of those laboratory science departments that remain undersized relative to peers, namely Biological Sciences, Chemistry, and Physics, and the continuation of our initiative to rebuild our Psychology Department. We also recognize the fundamental importance of maintaining the size and strength in our other departments and in sustaining preeminence in our highest-ranked department, the Department of Earth and Environmental Sciences (DEES). We are therefore committed to modest growth across the sciences, to continuing to build Ecology, Evolution, and Environmental Biology (E3B), and to paying particular attention to opportunities for outstanding hires in Astronomy, Mathematics, and Statistics—departments not requiring significant immediate growth but in which strategic hires over the next five years are key to success:

- **Psychology** must have a net increase in size by five to seven faculty in order to remain competitive. Recruitment will take place across a range of subdisciplines and will, over time, ensure balance between junior, mid-career, and senior recruits. A third of the new recruits should be at the senior faculty level. These recruitments will be coordinated with the Mind Brain Behavior Initiative where applicable. We are planning for searches in Psychology with the expectation of approximately eight to thirteen replacement hires in the ten-year time frame.

- **Biological Sciences** must continue to replace key anticipated retirements and begin to grow to a size comparable with our peer institutions. The Biological Sciences Department is the laboratory science department most in need of growth. Searches will be guided by priorities identified in the Biological Sciences strategic plan, such as chemical and structural biology, stem cells, genetics, neuroscience, cancer biology, and computational systems biology. Searches will be targeted at the junior and mid-career level to maximize the
growth trajectory and to increase the seniority balance within the department.

- **Physics** must continue hiring to complete the Theory Initiative and begin a Condensed Matter/AMO Initiative. With the build-out of the eleventh-floor NWC Building allocated to Physics and some outstanding hires, the Physics Department will have an opportunity to solidify its standing as a leader in condensed matter/AMO physics while retaining strength in other traditional subdisciplines.

- **Chemistry**, due to imminent retirements of some eminent chemists, must begin meeting some of the following high-priority needs: rebuild our presence in physical chemistry, protect and renew our historically singular international presence in synthetic and mechanistic chemistry, continue to develop visibility and presence in materials chemistry, and increase stature in inorganic chemistry.

- **DEES**, in order to retain its preeminent status, must add a specialist on the ice dynamics and/or glacial response to climate change and a stable isotope specialist with interest in Earth-life interactions. Other priorities include environmental chemistry, experimental petrology and geochemistry, carbon cycle, Earth resources, biogeoscience (to continue our expansion), and the study of geologic hazards (natural and anthropogenic).

- **E3B**, our youngest department, needs to continue to grow in the fields of genetics/population biology, evolution of life including the human species, marine biology, conservation biology, and environmental biology/sustainability science.

- **Statistics**, a field central to the Institute for Data Sciences and Engineering, must pursue hires to solidify its pillars of strength in targeted research areas.
FACILITIES

MAJOR CAPITAL INVESTMENTS FOR SHARED FACILITIES

Develop and support core facilities
• Define space and funding needs, and select faculty leadership:
  + Center for Advanced Biological Imaging
  + Biomolecule Characterization Facility
  + Biochemical and Biophysical Interactions Characterization Core Facility
• Expand the proteomic core to include genomic and metabolomic technologies.
• Define additional space and funding needs, select faculty leadership, integrate with hiring priorities.

Improve access to state-of-the-art computational facilities
• Implement recommendations of the Shared Research Computing Policy Advisory (SRCPA) Committee to allow shared investments in high performance computing.

Obtain support in Astronomy for access to a major telescope
• Fund participation in a major telescope facility, as prioritized in the Astronomy Department strategic plan, which will enhance department contributions to key open questions—dark energy, galaxy formation, and extra-solar planets.
• Increase our ability to attract the top faculty, postdoctoral fellows, and graduate students.

Renovate space for the Center for Galactic Origins
• Identify and renovate appropriate space for this second founding center in the Origins theme.

Complete construction in the Pupin Theory Center
• In conjunction with the coordinated strategic hiring plan of the Physics Department, complete construction of the Pupin Theory Center.

Begin construction in the Schermerhorn Research Greenhouse
• Begin construction of a working research greenhouse for faculty and student use, including all basic infrastructure.

Identify additional space for the Department of Statistics
• To support Statistics faculty growth, identify space for expansion.

RENOVATIONS TO ENABLE RECRUITMENTS AND MAINTAIN STATE OF GOOD REPAIR IN SCIENCE BUILDINGS

Begin renovations for Mathematics graduate student center
• Work with the provost and the registrar to swap classrooms in different buildings in order to create additional graduate student space for Mathematics.

Build out the eleventh floor of the Northwest Corner Building
• To support Physics hires in the Condensed Matter/AMO Initiative, outfit wet labs and offices for four new recruits.

Begin renovations in Havemeyer and Chandler
• Begin renovations to support Chemistry hires.

Establish a more significant physical presence for the Department of Earth and Environmental Sciences (DEES) on the Morningside campus
• Establish a presence for DEES that can be used to support additional outreach and student services to undergraduates and to integrate operations between the Lamont campus and the Morningside campus.

Renovate Fairchild
• Renovate Fairchild to support Biological Sciences, including a near-term urgent refreshment of the wiring and switches in the building that is needed to support normal computational usage. Plan for necessary upgrades of the environmental rooms in Fairchild.

Begin renovations in Schermerhorn
• To support Psychology and E3B, begin implementation of the long-term space plan for these departments.

Maintain and update the Nevis Laboratories
• Ensure that these essential facilities remain available and in good repair for research in the Origins research theme.
**ARTS AND SCIENCES–WIDE INITIATIVES**

**Endow three additional postdoctoral fellows for the Columbia Prize Fellows Program**
- Raise endowment to support three named postdoctoral fellowships in the sciences at Columbia University. Recruit the best early-career scientists into these positions and make major efforts to ensure a high profile for the named fellowships.

**Faculty chairs**
- Raise endowment funding for named faculty chairs in several departments.

**Support for the Bridge Program**
- Raise additional current use funding and target an endowment for an ongoing institutionalized Bridge Program, a highly successful University investment in creating opportunities to enhance the participation of students from underrepresented groups in PhD programs in the natural sciences.

**Support for graduate student fellowships**
- Raise support to endow graduate fellowships.

**Support for undergraduate research opportunities**
- Raise support to endow undergraduate research opportunities.

**FUNDRAISING**

By 2017 there should be a fully functioning Advisory Board for Science, meeting at least once every year and supported with staff engagement from the Office of Alumni and Development and Arts and Sciences at a high level. We expect that the board will be made up of alumni and friends of the University and will continue to assist Arts and Sciences with its science priorities, enumerated in the strategic plan.

Photo courtesy of Kevin Anchukaitis, adjunct associate research scientist, Lamont-Doherty Earth Observatory.
LONG-TERM GOALS (Ten Years)

FACULTY
Recruit for additional new hires in most departments
- Make aggressive strategic recruitments, leveraging investments in facilities, to make recruitments across the sciences at all levels, replacing retiring faculty and augmenting with additional faculty lines.
- Complete overall faculty growth in sciences of approximately 15 percent over the AY 2013 baseline.

FACILITIES
MAJOR CAPITAL INVESTMENTS FOR SHARED FACILITIES
Complete construction of the Schermerhorn Research Greenhouse
- Complete construction of a working research greenhouse for faculty and student use including sophisticated growth chambers.

Establish the financial stability of core facilities
- Leverage government grants, private philanthropy, and foundation support with strong faculty leadership to ensure the long-term viability and technological competitiveness for essential facilities in the Life theme:
  + Center for Advanced Biological Imaging
  + Biomolecule Characterization Facility
  + Genomic, Proteomic, and Metabolomic Core
  + Nanofabrication Laboratory
  + Transmission Electron Microscopy Laboratory

NECESSARY RENOVATIONS TO ENABLE RECRUITMENTS AND MAINTAIN STATE OF GOOD REPAIR IN SCIENCE BUILDINGS
- Havemeyer and Chandler to support Chemistry hires
- New spaces on Morningside identified for recruits in Psychology and E3B
- Fairchild to support Biology
- Pupin to support Astronomy
- Schermerhorn to support DEES and Psychology
- Nevis Laboratories maintained and construction begun for necessary updates

E3B professors Ruth DeFries and Shahid Naeem encounter a samba deer (Rusa unicolor), a species whose status is listed by the International Union for Conservation of Nature as vulnerable, during a research trip to India.
ARTS AND SCIENCES–WIDE INITIATIVES

Endow remaining six postdoctoral fellows for Columbia Prize Fellows Program
- Raise endowment to support an additional six named fellowships in the sciences at Columbia University. Recruit the best early-career scientists into these positions and continue to ensure a high profile for the named fellowships.

Endow additional faculty chairs
- Raise endowment funding for named faculty chairs in several departments, to support faculty growth plans.

Endow graduate fellowships
- Raise endowment funding for named graduate fellowships.

FUNDRAISING

By 2023, the Advisory Board should be sufficiently mature to effectively support science fundraising priorities into the next decade.

Top: Chemistry professor Ruben Gonzalez is using state-of-the-art single-molecule microscopy to study the process through which ribosomes synthesize proteins at unprecedented resolution.

Center: Scanning tunneling microscopy image of a single nitrogen atom embedded in monolayer graphene. Physics professor Abhay Pasupathy uses scanned probe microscopes to obtain atomic-resolution structural and electronic information on quantum materials.

Bottom: An Earth and Environmental Sciences graduate student in the Navaho sandstone formations of Utah. Photo courtesy of former DEES graduate student Sheila Xiah Kragie.
CONCLUSION

This strategic plan shows a dedicated path toward achieving an ambitious long-term vision for our nine science departments over the upcoming decade. The resource requirements and effort involved in implementing this plan are significant, but with the proper investment, Columbia's nine science departments will achieve preeminent stature—research productivity will be enhanced, new educational opportunities will be created, and Columbia will be increasingly known as the source of exciting new scientific output in the public eye. Recognizing our historical greatness in science—from understanding the tiniest building blocks of matter and life, to answering our questions about the vast cosmos—this plan outlines a way to sustain Columbia's legacy in science and carry us forward as scientific leaders into the next century.

The strategy outlined in this plan will allow science at Columbia to continue and grow its reputation as one of the top science institutions in the world. This will require recruiting the best faculty in their fields who are driving the emerging areas of science, upgrading the physical infrastructure needed to recruit and retain the best students and faculty, and developing deliberate programs to accelerate the highest-impact research among students and faculty. This plan focuses on specific, carefully considered methodologies to ensure that our investments in science make the largest possible impact.

The future of science research at Columbia demands a rededication to the University's legacy of scientific research, innovation, entrepreneurship, and technological leadership. Reaching that goal will require ensuring that a good number of the world's leading scientists are attracted to and remain at Columbia. It will require supporting them in state-of-the-art facilities and facilitating their engagement with colleagues to forge new ways of thinking about the new problems our world faces today.

“We should be grappling with the most exciting and profound scientific questions in a university like Columbia, where we have the strength in the social sciences and humanities to place new discoveries in the proper societal context, and where great links exist and can be strengthened between science on the Morningside campus, SEAS, and CUMC.”

—Mike Purdy, Executive Vice President for Research
“With the acquisition of the Manhattanville campus, an enormous opportunity has been created to define a bright intellectual future. This plan provides a blueprint for developing a key component of the intellectual core of that activity.”

—John Coatsworth, Provost

“Columbia Science is laying a bold and ambitious path toward preeminence in the basic sciences. Science and Engineering have been great partners in pursuing frontier research at Columbia. I am excited about the synergy of the Science plan with emerging directions in SEAS as we approach our 150th anniversary and chart our future.”

—Mary C. Boyce, Dean of The Fu Foundation School of Engineering and Applied Science

On the front cover (clockwise from top right): An inside view of the ATLAS experiment, courtesy of CERN; a wrinkled bacterial colony from the lab of Biological Sciences professor Lars Dietrich, who studies the mechanisms of pattern formation in bacterial communities; microscopic image of live Foraminifera, small marine protists that live in the surface ocean and host symbiotic algae (bright yellow dots) on spines radiating from their central shell; a sagittal view of the human brain obtained with functional magnetic resonance imaging (fMRI) courtesy of Psychology professor Daphna Shohamy, who studies the cognitive neuroscience of learning, memory, and decision making; Earth and Environmental Sciences graduate students exploring a sub-glacial ice cave (photo continues onto back cover).