New paper info goes here... this year book contains 30% post-consumer recycled fiber. By using recycled fiber in place of virgin fiber, the Carnegie Institution preserved 13.25 trees, saved 28 pounds of waterborne waste, saved 5,627 gallons of water, and prevented 1,226 pounds of greenhouse gasses. The energy used to print the report was produced by wind power. Using this energy source for printing saved 2,627 pounds of CO2 emissions, which is the equivalent to saving 1,786 miles of automobile travel.

Design by Susan K. White
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Since the founding of the institution, Andrew Carnegie’s vision has remained steadfast—“to encourage, in the broadest and most fundamental questions on the frontiers of biology, earth sciences, and astronomy.” The Carnegie Institution was incorporated with these words in 1902 by its founder, Andrew Carnegie. Since then, the institution has remained true to its mission. At six research departments across the country, the scientific staff and a constantly changing roster of students, postdoctoral fellows, and visiting investigators tackle fundamental questions on the frontiers of biology, earth sciences, and astronomy.

About Carnegie
Contents

The President’s Commentary  6
Friends, Honors & Transitions  17
Research Highlights  27
Financial Profile  56
Carnegie Investigators  63

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The Ring of Brodgar is a Neolithic site in Orkney, Scotland, that is 104 meters in diameter. The purpose of the ring of stones is unknown.

Carnegie president Matthew Scott stands next to a bust of Andrew Carnegie in Dunfermline, Scotland.

Weaving Together Carnegie Science

The weaver hurled the steel-tipped shuttle across parallel lines of warp threads, about half the threads lifted by a comb-like heddle. The loom was a Jacquard loom of the type often used in the mid-1800s. We were standing in a cottage in Dunfermline, Scotland, where Andrew Carnegie was born in 1835.

Carnegie’s father William, a handloom weaver, spent years producing damask in this room before steam-powered looms and industrial weaving put him out of work. The street level of the Dunfermline cottage was entirely devoted to weaving. Upstairs two families lived, one in each of the two rooms. William’s craft placed him among...
Andrew Carnegie’s Origins

Andrew Carnegie was born in this cottage in 1835. The bottom floor was reserved for weaving and housed a Jacquard loom. The Carnegie family lived in one upstairs room. Weaving intricate patterns is determined by the order in which heddles, the comb-like pieces that separate the threads, are raised and lowered. At the end of the 1700s, weavers used cards with punched holes to instruct the order in which heddles were raised or lowered. This technique was a precursor to computer punch cards.

the aristocracy of workers, but you would not know it from the space shared by the four members of the family. With 12-year-old Andrew, and the rest of the family, they sold everything to purchase tickets and soon embarked for America on the ship Wiscasset, a former whaler built in Maine.

In 1881, Andrew came back in gratitude to leave a lasting impact upon Dunfermline. The first of the more than 2,400 libraries he created around the world was built in Dunfermline; it stands a short distance from his cottage. Not far away, Dunfermline’s spectacular church is graced with stained glass from the Carnegie family, and Carnegie Hall (not that one) hosts Celtic music and fine theater. The auditorium, like ours at P Street headquarters, has been under renovation.

Damask patterns are intricate, and weavers devised ways to simplify the process of creation: they used codes. On a loom, each heddle is threaded with a specific group of warp threads, for example—alternate threads, so that lifting different heddles or combinations of heddles will give rise to patterns; the shuttle carries the weft thread across the loom either above or below sets of warp threads. Complex patterns are created by the order in which heddles or sets of heddles raise and lower the warp threads. At the end of the 1700s, new technology automated loom programming, in a way similar to the way player pianos were later programmed: cards with punched holes served as a code for the individual warp threads in each row. A thread would be raised or stopped according to whether its guiding hook found a hole or solid material in the punch card above. Later the idea of using hole patterns in cards to carry such codes became the basis for computer punch cards that were used in the 1970s by computer programmers. Thus the technology used by William Carnegie connects directly to modern computer programming, but we use electronic ones and zeroes now instead of the presence or absence of a punched hole.

What would William or Andrew think if they could see the Carnegie high-performance computing (HPC) facility we have constructed at Stanford? This HPC
Giving Back
Andrew Carnegie’s success allowed him to give back to Dunfermline.

The first of the 2,400 Carnegie libraries was built there. He also donated stained glass to adorn the church and built Carnegie Hall, where performances are still held in the auditorium.
resource will serve members of all our Carnegie departments and will allow a speed and sophistication of computational science that is now required for many, perhaps most, of our scientific projects. For much of the past year a team composed of representatives from each Carnegie Science department has met to shape our future computational needs in light of specific projects that are in progress or on the horizon. They considered both hardware and software needs and what sorts of skilled staff will be needed to fully exploit the potential of the new facilities. From this effort emerged a dynamic plan, which we are putting into action now. Visualizing, analyzing, and modeling the origins of the universe; deciphering fluctuations of gene activities during development; measuring and modeling dynamic fluxes of tectonic and convective movements within the Earth; modeling the properties of never-before synthesized chemicals at high pressures; analyzing properties of families of proteins; assessing chemical and physical properties of developing planets; or testing properties of tens of thousands of mutant algal cells. All these and more require new approaches and very fast computing.

What makes these plans particularly important and exciting to me is the "organic" unification of our scientists that happened along the way. When was the last time plant biologists, astronomers, and geophysicists had a common language? Each had to explain to the others their goals, their kinds of scientific questions, their approaches, and what sort of computational staff and infrastructure would be needed to succeed. As these discussions continue they may well deepen into collaborations, where an analogy between analyses being done in these different fields turns into a method that serves widely different fields of science.

New High-Performance Computing Center

Scientific computing is fundamental to the missions of world-class research institutions. Carnegie embarked on a new high-performance computing (HPC) facility, located at Stanford University. It will serve members of all Carnegie departments. A team was formed from representatives from each department to define future computational needs. They focus on four main areas—scientific visualization, big data and data mining, scientific programming and algorithm developments, and education and outreach. The center will allow the speed and sophistication that computational science now requires for many of Carnegie’s projects.

The state-of-the-art facility, shown from above and up close, is highly energy efficient. A passive cooling system resides on the roof. It has a diesel back-up generator and flywheels allow uninterrupted power. The facility can house 180 racks. There are nearly 100 racks already operational; among them are a Cray cluster, Stanford’s Sherlock cluster, and Carnegie’s Memex cluster.
Visualization is a good example, the interpretation of complex patterns in space and time—woven textures of planets and galaxies, evolution of minerals and organisms in concert, fluctuating organelles in moving and dividing cells, seismic flows deep underground, chemical responses of forests to seasons and climate change and fires. Computers “see” patterns within patterns, absorbing and recognizing features not easily spotted by a human staring at a screen. Viewing scientific data in new and powerful ways allows scientists to understand better, a first step toward new hypotheses and experiments.

The beautiful patterns created by William Carnegie and his artistic peers reflect colors and textures of the Scottish countryside. In the same way, the elegance of scientific insights coming from observation, experimentation, deduction—and often computational analysis—reflect the wonderful community and rich textures of Carnegie Science. Equipped with new ideas and new tools, we look forward to another extraordinary year.

President, Carnegie Science
Lifetime Giving Societies

The Carnegie Founders Society
Andrew Carnegie, the founder of the Carnegie Institution, established it with a gift of $10 million, ultimately giving a total of $22 million to the institution. His initial $10 million gift represents a special amount. Thus, individuals, including those who have directed contributions from private foundations and donor-advised funds, who support Carnegie with lifetime contributions of $10 million or more are recognized as members of the Carnegie Founders Society.

The Edwin Hubble Society
The most famous astronomer of the 20th century, Edwin Hubble, was a Carnegie astronomer. His observations that the universe is vastly larger than we thought, and that it is expanding, shattered our old concept of cosmology. Science often requires years of work before major discoveries like his can be made. The Edwin Hubble Society honors those whose lifetime contributions have helped the institution to foster such long-term, paradigm-changing research by recognizing those who have contributed between $1,000,000 and $9,999,999, as well as those individuals who have directed contributions to the Carnegie Institution at that level from private foundations and donor-advised funds.

The Vannevar Bush Society
Vannevar Bush, the renowned leader of American scientific research of his time, served as Carnegie’s president from 1939 to 1955. Bush believed in the power of private organizations and the conviction that it is good for man to know. The Vannevar Bush Society recognizes individuals who have made lifetime contributions of between $100,000 to $999,999, as well as those individuals who have directed contributions to the Carnegie Institution at that level from private foundations and donor-advised funds.

The Second Century Legacy Society
The Carnegie Institution is now in its second century of supporting scientific research and discovery. The Second Century Legacy Society recognizes individuals who have remembered, or intend to remember, the Carnegie Institution in their estate plans and those who support the institution through other forms of planned giving.

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(Gifts Received Between July 1, 2014, and June 30, 2015)

The Barbara McClintock Society
An icon of Carnegie science, Barbara McClintock was a Carnegie plant biologist from 1943 until her retirement. She was a giant in the field of maize genetics and received the 1983 Nobel Prize in Physiology/Medicine for her work on patterns of genetic inheritance. She was the first woman to win an unshared Nobel Prize in this category. To sustain researchers like McClintock, annual contributions to the Carnegie Institution are essential. The McClintock Society thus recognizes generous individuals who contribute $10,000 or more in a fiscal year, as well as those individuals who have directed contributions to the Carnegie Institution at that level from private foundations and donor-advised funds.

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The Boeing Gift Matching Program
The Bodman Family Foundation
The Michael T. Long Family Foundation
The Crawford Family Foundation
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Honors

Embryology
Marnie Halpern was named a Fellow of the American Association for the Advancement of Science. Junior Investigator Zhao Zhang received the prestigious Larry Sandler Memorial Award of the Genetics Society of America. The annual award is given for the best research that led to a Ph.D. using the fruit fly Drosophila.

Geophysical Laboratory
Anat Shuchar was awarded the Clarke Award of the Geochemical Society. It is awarded to an early-career scientist for “a single outstanding contribution to geochemistry or cosmochemistry, published either as a single paper or a series of papers on a single topic.”

Global Ecology
Chris Field, director of Global Ecology, was awarded the fifth annual Stephen H. Schneider Award for Outstanding Climate Science Communication by Climate One. The American Geophysical Union (AGU) bestowed him with the 2014 Roger Revelle Medal. Joseph A. Berry was elected to the National Academy of Sciences. Greg Asner was elected a Fellow of the American Geophysical Union (AGU).

Observatories
Carnegie astronomer Mark Phillips, interim director of the Las Campanas Observatory, is one of a group of scientists honored with the Breakthrough Prize in Fundamental Physics.

Plant Biology
Director Wolf Frommer was elected a member of the German Academy of Sciences, Leopoldina, one of the world’s oldest national academies. Zhiyong Wang received the Humboldt Research Award, one of Germany’s most prestigious prizes. David Ehrhardt was awarded an honorary fellowship of the Royal Microscopical Society.

Terrestrial Magnetism
Sean Solomon, director of Carnegie’s Department of Terrestrial Magnetism from 1992 until 2012, received the nation’s highest scientific award, the National Medal of Science. Erik Hauri was made a fellow of both the Geochemical Society and European Association of Geochemistry.
Transitions

Administration
Timothy Doyle joined Carnegie as Chief Operating Officer. He was Associate Dean for Finance and CFO for Harvard’s School of Engineering and Applied Sciences (SEAS). Doyle has a unique blend of experience including complex administrative and financial organizations, private sector businesses, and most recently the research and education sectors. His diverse financial and operations background spans the areas of strategic leadership, financial systems and controls, budgeting and planning, and administration efficiency.

Margaret Moerchen was appointed Science Deputy to the President. She is an astronomer and was associate editor of Science magazine where she handled all astronomy and planetary science manuscripts. Her interactions at the journal enhanced her knowledge of other physical sciences including geophysics, climate science, chemistry, materials science, and physics. Previously, she worked on instrument-building teams at the world’s largest telescopes, collaborating with diverse scientists and engineers.

Observatories
John Mulchaey was appointed the Crawford H. Greenewalt Director of the Carnegie Observatories. Mulchaey has been at Carnegie for 20 years. He investigates groups and clusters of galaxies, elliptical galaxies, dark matter—the invisible material that makes up most of the universe—active galaxies, and black holes. Although Mulchaey works extensively with space-based, X-ray telescopes, the optical telescopes at Carnegie’s Las Campanas Observatory play a central role in his research for follow-up observations, which are necessary to determine galaxy type and distance.

Terrestrial Magnetism
Richard Carlson was appointed director of Terrestrial Magnetism. He has been with Carnegie since 1980, originally as a postdoctoral fellow. Carlson studies the chemical and physical processes that formed the terrestrial planets. Using the known decay rates of various radioactive isotopes, he investigates the chronology of early processes on small planetary objects and studies the chemical and physical aspects of old and young crust-forming processes on Earth. He also studies nucleosynthetic differences in the early solar nebula.
Astronomy
Investigating the Birth, Structure, and Fate of the Universe

Small Galaxies, Big Impact

Nonastronomers might assume that the universe’s tiniest galaxies do not matter much on a cosmic scale. But the Observatories’ Josh Simon spends much of his time demonstrating that we can learn a great deal from the smallest galaxies.

Dwarf galaxies often orbit larger systems like our Milky Way, at distances between 75,000 and more than 1 million light years. Simon’s research ranges from “garden-variety” dwarf galaxies, containing millions of stars, to the recently identified “ultra-faint” dwarf galaxies, with only a few thousand stars. Most of the Milky Way’s larger dwarf satellites, such as the Sculptor dwarf spheroidal galaxy, were discovered decades ago by former Carnegie astronomers Harlow Shapley, Albert Wilson, and Robert Harrington. But ultra-faint dwarfs came to light only in 2005 with the advent of deep digital sky surveys.

By measuring stellar motions within the ultra-faint dwarfs, Simon and colleagues showed that they are surprisingly heavy. These galaxies weigh nearly as much as ordinary dwarfs despite hosting many fewer stars. Simon’s measurements demonstrated that ultra-faint dwarfs are made almost entirely of dark matter—the invisible matter that makes up most of the universe. Less than 1% of their mass consists of ordinary matter like protons, neutrons, and electrons, and 99% to 99.97% of their mass is dark matter. As a result, these smallest dwarfs have become the center of attention for particle physicists and astronomers studying dark matter.

The whopping dark matter content is not the only surprise. Simon, Anna Frebel of MIT, and their collaborators unexpectedly found that the abundance of elements like magnesium, calcium, and titanium in ultra-faint dwarf galaxy stars is almost identical to the abundance of those elements in similarly old Milky Way stars. Heavier elements such as barium and strontium, however, are much rarer in the dwarf galaxies; their absence may provide a clue as to how such elements are created by supernova explosions.

The latest development has been the discovery of many previously undetected dwarfs near the Milky Way by the Dark Energy Survey, among other efforts. Remarkably, a total of 23 dwarf galaxy candidates have been identified in just three months this spring, compared to only 26 Milky Way satellites known prior to 2015. Most of the new discoveries are deep in the southern skies, perfectly positioned for observations with the Magellan telescopes at Carnegie’s Las Campanas Observatory in Chile. Simon expects that this cornucopia will keep him—and Magellan—busy for years to come.
Relighting the Universe

The universe cooled furiously after the Big Bang, 13.7 billion years ago. Atoms assembled some 400,000 years later, with cooler temperatures allowing protons to join with electrons, forming hydrogen and clearing the murky gas. After about 500 million years the first galaxies began to form. Astronomers think that the intense energy of galactic star formation unbound the electrons in the hydrogen gas, in a period of “reionization” lasting from 500 million to 1,000 million years.

Alan Dressler looked for the faintest of these early galaxies to learn if they are abundant and energetic enough to drive reionization. Through a novel method, he was able to find galaxies five times fainter than before and reveal 25 times as many galaxies, enough to supply 25-50% of the ultraviolet light needed to reionize the universe: they are likely reionizing agents.

Telescopes witness the distant and young universe in real time. It is hard because the first galaxies were small and their starlight is feeble. Hubble Space Telescope images, however, reveal a sample of thousands of galaxies from the reionization epoch, but the total ultraviolet light from star formation in them is only about 10% of the amount needed.

The speculation has been that galaxies fainter than those found by Hubble supplied most of the energy for reionization. However, the deep imaging technique used could not find fainter galaxies. Dressler pushed fainter via a method developed by collaborators Crystal Martin (UC-Santa Barbara) and Marcin Sawicki (St. Mary’s) that uses spectroscopy, the analysis of the light’s spectrum, over the narrow band of imaging. With the Inamori-Magellan Areal Camera and Spectrograph (IMACS) on Magellan at Carnegie’s Las Campanas Observatory, Dressler conducted a blind search covering 10% of the field of view by restricting the incoming wavelength to 150 angstroms of the 1500 angstroms typically observed. (An angstrom is a unit of length equal to one ten-billionth of a meter.) The light passing through each of 100 parallel “long slits” was dispersed to search for so-called Lyman-alpha emission lines, the signature light produced by gas glowing from star formation. Dressler looked for galaxies at the end of the reionization epoch.

The numbers of detected emission lines rises steeply with decreasing brightness. Weeding out foreground galaxies by taking additional deep spectra of 60 representative targets confirmed that 1/3 of the faint sources are early-universe galaxies—a dramatic rise in the number of faint, early-universe galaxies, enough to reionize the universe.
STEM Gets Stronger

In October 2014, the Carnegie Academy for Science Education (CASE) joined forces with the District of Columbia Office of the State Superintendent of Education (OSSE) to launch the DC STEM Network. (STEM is Science, Technology, Engineering and Math.) This network is uniting community partners to design, guide, and advocate for improving STEM learning opportunities for Washington, D.C., students. The D.C. network joins initiatives in 22 states as part of a nationwide network led by the Battelle Memorial Institute. An advisory council of community leaders and a leadership team govern the network; CASE and OSSE staff provide backbone support.

With over 20 years in D.C. teaching students and teachers about STEM, CASE is ideal to lead the program.

In March, CASE hosted a launch event, engaging 120 educators, industry partners, and community leaders in student-led lab experiments and interactive workshops that created seven working groups to increase access to STEM learning. The working groups cover mentoring and tutoring, in-school education, out-of-school educational opportunities, professional development for teachers, and community outreach. Each working group developed and implemented an action plan. Outcomes from each of the working groups’ activities were reported on at a DC STEM Summit in November 2015.

In July, CASE and OSSE trained 11 D.C. classroom teachers to become STEM ambassadors in the city to increase community engagement with the education efforts of the network. In August, Carnegie cohosted the STEM Leadership Academy with the Center for Inspired Teaching and OSSE. Thirty-four D.C. principals attended the two-day event to learn about the implementation of the Next Generation Science Standards and the Common Core State Standards for Mathematics, as well as interdisciplinary instruction. The standards are based on a framework developed by the National Research Council rendered by educators in 48 states. The goal is to teach science in a manner that mirrors the way science and engineering professionals approach their everyday work and to stress critical thinking and communication skills.
The Carnegie Academy for Science Education & Math for America

Continued

Master Teacher Program Expands

National Math for America (MfA) is excited to announce the expansion of the Master Teacher Program, with the goal to establish a model for a corps of national master teachers in mathematics and science. This approach follows a recommendation from the 2010 President’s Council of Advisors on Science and Technology (PCAST) report urging the formation of a nationwide STEM Master Teacher Corps. MfA also seeks to make teaching a respected career choice for the best minds in science and mathematics.

To qualify for the MfA DC Master Teacher Program, candidates need a strong math background, must have taught math for at least four years, and must have demonstrated leadership qualities. The rigorous selection process includes a complex application, PRAXIS exams, and an interview with a selection panel. If selected, the master teachers commit to teaching five years in the Washington, D.C., public schools. MfA DC Master Teachers receive a $10,000 salary supplement to reward their teaching excellence and encourage retention. They also receive a one-time grant to further their education, attend professional math meetings, or work toward National Board certification.

The MfA DC Master Teacher program started in 2011 and now includes nine Master Teachers from among those currently teaching mathematics in D.C. public or public charter schools. Three are alumni of the first cohorts of fellows, one is the 2011 Presidential Awardee for Excellence in Mathematics and Science Teaching, and another is the 2014 D.C. Teacher of the Year.

Over four years, MfA DC teachers could potentially teach some 32,000 D.C. students.

As part of the expansion, MfA DC hopes to recruit five Master Teachers per year over the next five years. In 2015, eight teachers applied and four were selected. Currently, there are 33 MfA DC teachers in the pipeline. These highly effective teachers strive to provide outstanding mathematics instruction; they impacted approximately 8,000 D.C. students in the public secondary schools last year. Over four years MfA DC teachers could potentially teach some 32,000 D.C. students.

MfA DC is directed by Bianca Abrams. Assistant director Paul Penniman was hired in 2015 to lead the expansion and its professional development. He has taught mathematics since 1978. He is the founder and executive director for Resources to Inspire Students and Educators (RISE), a nonprofit that has provided tutoring and mentoring to low-income D.C. youth, primarily in Wards 7 and 8, for the past 12 years.
The Mystery of Deep Water Cycling

Lara Wagner uses seismic imaging to unravel the mysteries of Earth's deep water cycle. Deep water cycling mostly occurs in subduction zones: plate boundaries where one tectonic plate slides under another. At subduction zones, old oceanic crust is returned to the hot mantle, new continental crust is made, volcanoes and earthquakes form, and water enters and exits Earth's interior. Water, in turn, may play a key role in explaining why—among the rocky, terrestrial planets—only Earth has plate tectonics. Wagner believes that observing certain minerals’ dehydration processes will help establish the steps in this water cycle. However, in most subduction zones, these steps almost all happen at nearly the same time and place, when the plate reaches the hot mantle and heats rapidly. This makes it difficult to tease them apart, or to know if any water is left behind in the sinking plate.

Wagner studies areas with “flat-slab subduction,” in Peru, Chile, and Colombia, where heating occurs much more gradually because contact with hot mantle is delayed. This gradual heating allows Wagner to analyze the sequential breakdown of water-laden minerals that formed when the oceanic plate was still under water. By studying flat-slab subduction, Wagner can study both the fate of the water that is progressively released at shallower depths and the water that remains in the downgoing plate to be transported deep into the Earth.

To study the fate of water in subduction zones, Wagner has been deploying broadband seismometers for over 15 years in Chile and Peru to produce high-resolution images of seismic velocities in the Earth's interior. Seismic velocities are very sensitive to the presence of water. Wagner expected to see evidence of this progressively released water in the continental plate directly above the subducted oceanic plate.

Wagner found evidence for water, but she also found evidence that this water changes the composition of the upper plate by adding silica from subducted sediments. The continental crust has, on average, substantially higher silica concentrations than does oceanic crust. This high silica concentration has long been thought to be related to the formation of continents in subduction zones, but the precise mechanism remains a mystery. Wagner’s work on the fate of subducted water continues, and her team is investigating ways to use smaller, lighter equipment to improve her ability to “see” water and its effects, deep in the Earth’s interior.

Both images (right) were rendered by Lara Wagner. The left image of a flat-slab subduction zone in Peru is from 1992 and was constructed using all available data at the time, most of which came from stations outside of South America. The one on the right, with much higher resolution, shows the tear on the northern portion of the flat slab where normal steep-dip subduction has reinitiated. The image is based on a model from Wagner’s graduate student Knezovic, Antonijevic. The more detailed image is based on data from 90 seismic stations that the team installed across Peru and Bolivia from 2010 to 2013. The local stations are key to “see” the structures below.

Installing seismic stations in remote field locations is time consuming and labor intensive. Lara Wagner (right) checks the data quality at one station in Peru. The team hopes to deploy smaller, lighter, seismic-sensing devices in the future.
Mercury Isn’t What We Thought

The MESSENGER (MErcury Surface, Space ENvironment, Geochemistry, and Ranging) mission to Mercury, including Deputy Principal Investigator Larry R. Nittler, has shattered what we thought we knew about the innermost planet, including its chemical composition and history. Surface chemistry maps recently revealed previously unidentified geochemical terranes—large regions with compositions distinct from the surrounding area.

Early in the mission, MESSENGER showed that Mercury’s crust was shaped by ancient volcanic magmas derived from the partial melting of the mantle. The team also found that the planet has an unusual sulfur-rich and iron-poor composition, indicating that it formed from a different mix of materials than the other terrestrial planets. The new maps reveal remarkable chemical diversity and are critical to understanding the processes that shaped Mercury’s mantle and crust.

...it formed from a different mix of materials than the other terrestrial planets.
A Natural “Band-Aid” for Wounds

Wound healing is short of miraculous. Traditionally, research has investigated how cell division replaces cells lost by injury. But what happens in organs that only have a limited capacity for cell division? Postdoctoral researcher Vicki Losick, in Allan Spradling’s lab, probed this question using the fruit fly *Drosophila melanogaster*. She studied healing in the adult fly’s abdominal epithelium, a thin layer of tissue below the fly’s exoskeleton. She found that wounds heal by cell growth instead of by cell division. In this case, the epithelial cells grew by polyploidization, a process by which cells can increase their DNA content resulting in two or more paired sets of chromosomes. By increasing a cell’s DNA content the cell can grow and support a larger cell volume. This is the first study demonstrating that polyploidy is essential to wound healing. Losick named this novel mechanism wound-induced polyploidy (WIP).

Losick has begun to uncover the underlying “signal transduction pathway” mechanism behind the healing activity of WIP. These pathways are molecular “bucket brigades,” in which molecules outside of a cell activate receptors at either the cell surface or inside the cell, which then trigger other molecules to respond to the stimulus. In this wound repair scenario, a pathway called Hippo, which controls the size of organs, is at work. Depending on the type of tissue, Hippo appears to sense cell loss and activate cell replacement either by WIP or by cell division. This new knowledge sets up the fascinating question of why cells would opt to grow big by WIP, instead of dividing, to heal a wound. Losick and Spradling speculate that polyploid cells provide advantages for the tissue, including stronger mechanical properties that help to stabilize the wound area.

Fruit flies and mammals share many similar genes making flies ideal for studying biological processes. The fruit fly has been used to study repair mechanisms in embryos and larvae, but research in adults, which uses WIP, is in its infancy. Polyploid cells have been observed following injury to many organs in our body, but their role in wound repair has remained unknown. The fly could be a valuable proxy for understanding the basic molecular mechanisms that regulate WIP, enabling the healing capacity of polyploid cells to be exploited to improve human wound healing.

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Finding Treasure in Junk

Most biologists study genes, which are only 1.5% of our genome. But since Zhao Zhang started graduate school, he has been fascinated by the most abundant elements in the rest of the genome, “junk” sequences called transposons. Also known as “jumping genes,” these elements were first discovered by Carnegie scientist Barbara McClintock more than half a century ago. Making up at least 50% of our DNA, transposons can copy themselves within the genome much like viruses can. These genetic gypsies can wreak havoc on genome stability and integrity, often disabling genes and probably even triggering cancer. Zhang is developing new techniques, using the fruit fly Drosophila melanogaster, to study these most mysterious residents of our genome.

Failure to silence transposons in germ cells, precursors to egg and sperm cells, is the surest path to animal extinction. For this reason, animals have evolved a system in germ cells to put transposons under control. In this system, which is ancient in evolution and widespread across species, a specialized group of small RNA molecules—piRNAs—team up with certain proteins and create a “genomic immune system” to destroy products from transposons and shackle them in germ cells. With his colleagues, Zhang has discovered and named a gene, qin, found across species, which plays an essential role in this system. Mutating this gene leads to transposons jumping around in germ cells and animals becoming sterile.

Compared with germ cells, we know surprisingly less about transposon activities in somatic cells—cells that produce other tissues. Do they jump at all? How do somatic cells control their activity? Does the activation of transposons cause any disease or lead to aging? If yes, can we use them as therapeutic targets?

Since transposons are present in our genome in multiple copies, sometimes thousands of copies, and current tools are not sensitive enough to capture the mobilization of individual elements, progress to address these questions is impeded. The Zhang lab is developing new tools to potentially capture single transposon jumping events with single-cell resolution and capable of probing insertion events in one cell from a large cell population. These new tools could bring us into a new era of transposon biology in somatic cells. They could help us understand ourselves at a different level and potentially provide another way to treat diseases, such as cancer.
Turbocharging Photosynthesis

Martin Jonikas combines plant science with engineering to improve photosynthesis—the conversion of water, carbon dioxide, and sunlight into plant food and oxygen—to improve crop yields. When photosynthesis first evolved, the atmosphere contained much more carbon dioxide than it does today. The carbon-fixing enzyme Rubisco worked so well that it sucked most of the carbon dioxide out of the atmosphere. Today though, Rubisco is starving for carbon dioxide, limiting the growth rate of many crops. Green algae and so-called C4 plants like corn, however, overcome this limitation. They highly concentrate carbon dioxide before delivering it to Rubisco, via so-called carbon-concentrating mechanisms. The dream is to transfer this mechanism to crop plants, which could increase their yields by up to 60%.

To achieve this goal, the Jonikas lab is collaborating with the labs of Howard Griffiths at the University of Cambridge; Alistair McCormick at the University of Edinburgh; Mark Stitt and Michael Schroda at the Max Planck Institute of Molecular Plant Physiology; Ursula Goodenough at Washington University, St. Louis; and Stefan Geimer at the University of Bayreuth in a project called Combining Algal and Plant Photosynthesis (CAPP). The team’s objectives are to identify the genes involved in the algal carbon-concentrating mechanism, to understand them, and finally to transfer this system to higher plants.

Of the 17,000 or so algal genes, five are known to be required for the carbon-concentrating mechanism. The team believes that at least a dozen more remain to be discovered. To identify the missing genes, the Jonikas lab eliminates genes individually to see if the carbon-concentrating system is affected. They use large-scale robotics to analyze hundreds of thousands of algal mutants for carbon-concentration defects.

Algae and higher plants have chloroplasts, the organelle that conducts photosynthesis. However, the algal chloroplast has a special subcompartment not found in higher plants called a pyrenoid, which forms the heart of its carbon-concentrating mechanism. Algae put Rubisco in their pyrenoids and then pump a high concentration of carbon dioxide into Rubisco. Although little is known about how the pyrenoid is assembled, the Jonikas lab is discovering new genes that encode protein components of the subcompartment. With the Griffiths lab, they are determining the molecular role of each component, and an understanding of how the pyrenoid is assembled is beginning to emerge. The McCormick lab is now working to introduce the newly discovered components into higher plants.

The top image shows the chloroplast in an algal cell, in green. The chloroplast contains a feature called the pyrenoid, gray encircling blue. The close-up of the pyrenoid at bottom shows Rubisco in blue.

The Jonikas lab carbon-concentrating mechanism team, including collaborators from the United Kingdom, are shown from left to right: Martin Jonikas, Luke Mackinder, Vivian Chen, Nicky Atkinson (University of Edinburgh), Elizabeth Freeman, Alistair McCormick (University of Edinburgh), Howard Griffiths (Cambridge University), Laila Paliou, Moritz Meyer (Cambridge University), and Alan Italura. Image courtesy Martin Jonikas.
Plant cells have an interior scaffolding of proteins called a cytoskeleton that directs the construction of the cell walls and plant growth. Environmental signals, like light, and hormones prompt this scaffolding to reorganize. Yet the molecular mechanisms for this activity are not well understood. Carnegie’s David Ehrhardt and team investigate this process in higher plants via real-time, live imaging. Their discoveries provide an important foundation for developing new crops and for understanding how conserved proteins work in both plants and animals.

The cytoskeleton includes protein arrays called microtubules. In rapidly growing cells, the microtubule network forms in a parallel array that wraps around the cell perpendicular to the main growth axis. Previously, Ehrhardt and colleagues showed how this array directs the delivery of cellulose synthase enzymes (cellulose is the main substance of cell walls) to the cell membrane and guides these enzymes as they synthesize the cell wall.

The team also looked at how the direction of a blue-light source influences a plant’s growth, a phenomenon called phototropism. The responsible blue-light receptor protein, phototropin, was discovered by Carnegie’s Winslow Briggs in the 1990s. Light perception through phototropin also drives a rapid rearrangement of the outer microtubule cytoskeleton in cells on the lit side of the plant stem.

Imaging data and genetic experiments revealed that the reorientation of the cytoskeleton by blue-light perception is driven by a protein known as katanin, which sever microtubules. Previously, katanin was thought to be important for the disassembly of microtubule arrays. The Ehrhardt group found that katanin also has a creative role. It severs the microtubules, where they intersect each other, creating new ends that can regrow and then themselves be severed. This results in a rapid amplification of a new array oriented at about 90° to the original. This was the first time researchers demonstrated how blue light drives changes in cytoskeleton reorganization.

The researchers are now investigating the role of the cytoskeletal rearrangement in regulating phototrophic growth, the signaling mechanism between phototropin and katanin, and the role of other cytoskeletal regulatory mechanisms in reorientation. They have discovered two proteins that appear to be essential for rapid reorientation and stabilization of the new ends, work that they are preparing for publication.

A microtubule array is visualized by live-cell imaging. The blue overlay shows a cascade of new microtubules generated from a single progenitor by sequential rounds of severing by the protein katanin and the growth of the severed ends. The new array is roughly orthogonal to the original.

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Redefining Forest Biodiversity

Traditionally, the number and types of species per unit area defines biodiversity. But this way of looking at forests creates a huge gap between these species-based studies and the large-scale ecosystem and biosphere studies that tell us how our planet functions, including how water, carbon, nutrients, and other fundamental properties of the biosphere cycle and shift. To this end, Carnegie’s Greg Asner and his Carnegie Airborne Observatory (CAO) team are using remote-sensing tools and tree-climbing fieldwork to get a much bigger picture of forest biodiversity—how a diversity of functions is arrayed across a landscape and how this relates to the more traditional species diversity.

In a series of papers published in 2014 and 2015, the CAO team learned how a range of forests and regions within forests differed from one another in terms of their contributions to the entire biosphere. They uncovered hidden mosaics of chemical variation across the topography of forest canopies in the Peruvian Amazon.

Thousands of tree and plant species are found in the Amazon. Each one synthesizes a complex portfolio of chemicals to accomplish a variety of functions that range from capturing sunlight to fighting off herbivores, to attracting pollinators and adapting to climate change.

These forests grow on an underlying geologic and hydrologic patchwork quilt, which also affects the diversity of chemical functions that forest plants undertake. Understanding the geographic variability of plant chemical activity is crucial to understanding the way an ecosystem functions on a large scale.

By improving our definition and understanding of biodiversity, Asner hopes that forest managers and policymakers will have a better understanding of how to protect a forest’s portfolio of functions, not just its individual “head count” of trees and other plants. Understanding a forest’s functional diversity is also crucial for assessing how climate change and human activities are altering these chemically unique ecosystems that have undergone millions of years of evolution and biogeographic construction to become the chemical mosaics that they are today.
They are now partnering with Google Earth Engine to scale up... to include the entire globe.
A Different Scenario for Deep CO₂ Cycling

Scientists can’t venture to the deep Earth. So to understand earthquakes, volcanoes, plate tectonics, and the planet’s evolution they mimic the Earth’s high-pressure and high-temperature conditions in the lab. Recently, Dionysis Foustoukos and Bjørn Mysen took a new approach to deciphering how certain materials are deeply cycled. They found that carbonate minerals in the Earth’s crust, where it slides under an adjacent tectonic plate (called subduction), may not recycle carbon dioxide (CO₂) for deep storage as effectively as previously thought. Instead, carbonate minerals may participate in melting processes that could contribute to the volcanic CO₂ emissions at subduction zones, where plates converge and chains of volcanoes called arcs arise.

Carbonate minerals contain the carbonate ion and a metal, such as iron or magnesium. As an oceanic crust sinks into the mantle, carbonates interact with other minerals, altering their chemistry. Understanding melt structure is important for deciphering volatile cycling of carbon (C), oxygen (O), hydrogen (H), nitrogen (N), and trace elements and metals.

The duo used Raman vibrational spectroscopy to analyze squeezed samples in a diamond anvil cell and to observe the melting processes. In this method, laser light interacts with molecular vibrations from a sample as it is subjected to extreme conditions. As molecules change, a shift in light energy occurs, yielding specific chemical “fingerprints.”

The investigators subjected water-saturated calcium- and magnesium-bearing carbonates to reducing and oxidizing conditions, in which electrons are lost or gained. The experiments were conducted at temperatures ranging from 750-2000°F (400-1100°C) and pressures between 4,400-28,000 times atmospheric pressure (442-2839 megapascals).

Melting occurred in the magnesium carbonate (MgCO₃)-magnesium oxide (MgO) system at 1550°F (850°C) and between 5,000 and 15,000 atmospheres. In the calcium carbonate (CaCO₃)-calcium oxide (CaO)-water (H₂O) system, melting occurred between 1100-1650°F (600-900°C) and pressures of 15,000-20,000 atmospheres (1.5-2 GPa). These pressures and temperatures correspond to about 50-60 miles (80-100 km) beneath the volcanic arc.

The results suggest that carbonate may not survive the transfer to sub-arc depths greater than 50 miles (80 km) and may start melting before the completion of dehydration at the slab-mantle interface, even at subduction zones with cold to intermediate temperatures. If correct, recycling of carbon into the mantle would be less efficient than previously thought, and a significant amount of CO₂ would likely be expelled via volcanoes.
Expanding High-Pressure Horizons

The science of matter under extreme pressures and temperatures was in its infancy when Ho-kwang (Dave) Mao started breaking high-pressure records over four decades ago. He continues to develop instrumentation and methods to redefine this frontier, where chemistry morphs, electrons become erratic, magnetism warps, and new materials are born. Mao’s legacy has expanded to China where he now leads the Center for High Pressure Science and Technology Advanced Research (HPSTAR).

Mao’s record-breaking work took off in 1975 when he and Peter Bell developed a diamond anvil cell, the workhorse of high-pressure research, which reached over 1,000,000 times atmospheric pressure. Today the field includes high-pressure chemistry, high-pressure crystallography, chemistry of the Earth’s mantle and core, deep Earth geophysics, physics and chemistry of giant planetary interiors, and high-pressure materials science. The diamond anvil cell squeezes matter between two perfectly aligned single-crystal diamond tips. Matter is then measured with a wide range of probes including synchrotron X-rays; neutrons; and optical, electrical, and magnetic devices. But there are limits to the pressure diamond can withstand without breaking.

Recently, other researchers developed diamonds made up of many smaller crystals that achieve pressures of over 6 million atmospheres (640 GPa). Pressures in the Earth’s core, for comparison, are about 3.5 million atmospheres (350 GPa), and the cores of gas giants range from 5.8 to 47.4 million atmospheres (580 to 4740 GPa).

Mao is adapting the diamond anvil cell to reach pressures beyond these current limits by shaping the pressure-bearing tips of the anvil with a focused ion beam. In another push to unleash the full potential of this field, the Chinese government established HPSTAR, led by Mao since September 2012, to become a leader in this area. It is modeled after Carnegie by supporting independence, advanced facilities, and a collaborative research environment. HPSTAR scientists explore the high-pressure worlds of physics, chemistry, technology, photon science, nanoscience, functional materials, energy science, superhard materials, and Earth and planetary interiors.

HPSTAR was first established in Shanghai, followed by laboratories in Changchun and Beijing. The center is projected to grow to 90 faculty members and 600 others including graduate students, postdoctoral fellows, visiting scientists, engineers, and administrative personnel in the next decade.
Financial Profile
for the year ending June 30, 2015 (unaudited)

The Carnegie Institution for Science completed fiscal year 2015 in sound financial condition due to the positive returns (+7.3%) of the diversified investments within its endowment; a disciplined spending policy that balances today’s needs with the long-term requirements of the institution and the interests of future scientists; and the continued support of organizations and individuals who recognize the value of basic science.

The primary source of support for the institution’s activities continues to be its endowment. This reliance on institutional funding provides an important degree of independence in the research activities of the institution’s scientists.

As of June 30, 2015, the endowment was valued at $991 million. Over the period 2001-2015, average annual increases in endowment contributions to the budget were 5.0%. Carnegie closely controls expenses in order to ensure the continuation of a healthy scientific enterprise.

For a number of years, under the direction of the Investment committee of the board, Carnegie’s endowment has been allocated among a broad spectrum of asset classes including: equities (stocks), absolute return investments, real estate partnerships, private equity, natural resources partnerships, and fixed-income instruments (bonds). The goal of this diversified approach is to generate attractive overall performance and minimize the volatility that would exist in a less diversified portfolio.

The Investment committee of the board regularly examines the asset allocation of the endowment and readjusts the allocation, as appropriate. The institution relies upon external managers and partnerships to conduct the investment activities, and it employs a commercial bank to maintain custody. The following chart shows the allocation of the institution’s endowment among asset classes as of June 30, 2015.

<table>
<thead>
<tr>
<th>Asset Class</th>
<th>Target</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Stock</td>
<td>37.5%</td>
<td>41.7%</td>
</tr>
<tr>
<td>Alternative Assets</td>
<td>55.0%</td>
<td>45.4%</td>
</tr>
<tr>
<td>Fixed Income and Cash</td>
<td>7.5%</td>
<td>12.9%</td>
</tr>
</tbody>
</table>
Carnegie's investment goals are to provide high levels of current support to the Institution and to maintain the long-term spending power of its endowment. The success of Carnegie's investment strategy is illustrated in the following figure that compares, for a hypothetical investment of $100 million, Carnegie's investment returns with the average returns for all educational institutions for the last fifteen years.

Carnegie has pursued a long-term policy of controlling its spending rate, bringing the budgeted rate down in a gradual fashion from 6+ % in 1992 to 5% today. Carnegie employs what is known as a 70/30 hybrid spending rule. That is, the amount available from the endowment in any year is made up of 70% of the previous year’s budget, adjusted for inflation, and 30% of the most recently completed year-end endowment value, multiplied by the spending rate of 5% and adjusted for inflation and debt. This method reduces volatility from year-to-year. The following figure depicts actual spending as a percentage of ending market value for the last 23 years.

In fiscal year 2015, Carnegie benefitted from continuing federal support. Carnegie received $22.8 million in new federal grants in 2015. This is a testament to the high quality of Carnegie scientists and their ability to compete successfully for federal funds in this period of fiscal restraint.

Carnegie also benefits from generous support from foundations and individuals. Funding from foundations has grown from an average of about $3 million/year in the period from 2000 to 2004 to $11 million in 2015. Within Carnegie’s endowment, there are a number of “funds” that provide support either in a general way or targeted to a specific purpose. The largest of these is the Andrew Carnegie Fund, begun with the original gift of $10 million. Mr. Carnegie later made additional gifts totaling another $12 million during his lifetime. This tradition of generous support for Carnegie’s scientific mission has continued throughout our history and a list of donors in fiscal year 2015 appears in an earlier section of this year book. In addition, Carnegie receives important private grants for specific research purposes, including support from the Howard Hughes Medical Institute for researchers at the Department of Embryology.
### Statements of Financial Position (Unaudited)

**June 30, 2015, and 2014**

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assets</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current assets:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash and cash equivalents</td>
<td>$16,120,426</td>
<td>$4,092,370</td>
</tr>
<tr>
<td>Accrued investment income</td>
<td>73,772</td>
<td>11,988</td>
</tr>
<tr>
<td>Contributions receivable</td>
<td>7,077,572</td>
<td>11,280,393</td>
</tr>
<tr>
<td>Accounts receivable and other assets</td>
<td>8,966,680</td>
<td>9,188,678</td>
</tr>
<tr>
<td>Bond proceeds held by Trustee</td>
<td>49,434,798</td>
<td>49,414,262</td>
</tr>
<tr>
<td>Total current assets</td>
<td>81,673,248</td>
<td>73,988,691</td>
</tr>
<tr>
<td>Noncurrent assets:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investments</td>
<td>983,996,467</td>
<td>984,182,412</td>
</tr>
<tr>
<td>Property and equipment, net</td>
<td>137,996,467</td>
<td>140,153,915</td>
</tr>
<tr>
<td>Long term deferred assets</td>
<td>21,992,598</td>
<td>17,598,331</td>
</tr>
<tr>
<td>Total noncurrent assets</td>
<td>$1,143,605,259</td>
<td>$1,141,934,658</td>
</tr>
<tr>
<td><strong>Total assets</strong></td>
<td>$1,225,278,507</td>
<td>$1,215,923,349</td>
</tr>
</tbody>
</table>

| **Liabilities and Net Assets** |                           |                           |
| Accounts payable and accrued expenses | $30,145,114               | $11,234,976               |
| Deferred revenues          | 27,431,440                | 28,055,413                |
| Bonds payable              | 115,057,854               | 115,064,362               |
| Accrued postretirement benefits | 25,923,865                | 23,558,628               |
| Total liabilities          | $178,558,273              | $177,913,379              |

| **Net assets**            |                           |                           |
| Unrestricted              | $310,287,147              | $306,552,812              |
| Temporarily restricted    | 681,328,124               | 676,403,916               |
| Permanently restricted    | 55,104,963                | 55,053,242                |
| **Total net assets**      | $1,046,720,234            | $1,038,009,970            |

| **Total liabilities and net assets** | $1,225,278,507 | $1,215,923,349 |

### Statements of Activities (Unaudited)

**Periods ended June 30, 2015, and 2014**

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue and support:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grants and contracts</td>
<td>$37,738,760</td>
<td>$35,708,599</td>
</tr>
<tr>
<td>Contributions, gifts</td>
<td>10,610,849</td>
<td>10,438,061</td>
</tr>
<tr>
<td>Other income</td>
<td>6,213,102</td>
<td>2,645,768</td>
</tr>
<tr>
<td><strong>Net external revenue</strong></td>
<td>$54,562,711</td>
<td>$48,792,428</td>
</tr>
<tr>
<td>Investment income and unrealized gains (losses)</td>
<td>$58,482,948</td>
<td>$170,662,287</td>
</tr>
<tr>
<td><strong>Total revenues, gains, other support</strong></td>
<td>$113,045,659</td>
<td>$219,454,715</td>
</tr>
</tbody>
</table>

| **Program and supporting services:** |                           |                           |
| Terrestrial Magnetism | $11,769,589               | $12,858,902               |
| Observatories         | 18,318,574                | 19,181,747                |
| Geophysical Laboratory | 22,714,496               | 20,079,387                |
| Embryology            | 12,269,662                | 11,778,108                |
| Plant Biology         | 11,402,502                | 11,119,082                |
| Global Ecology        | 7,563,559                 | 8,432,635                 |
| Other programs        | 1,046,000                 | 1,250,486                 |
| Administration and general expenses | 17,975,643               | 14,205,604               |
| **Total expenses**    | $103,060,025              | $98,905,951               |
| Change in net assets before pension related changes | $9,985,634 | $120,548,764 |
| Pension related changes | (2,757,370)            | (2,440,448)               |
| **Net assets at the beginning of the period** | $1,046,009,970 | $1,038,009,970 |
| **Net assets at the end of the period** | $1,056,720,234 | $1,038,009,970 |

1 Includes restricted, temporarily restricted, and permanently restricted revenues, gains, and other support.
Small Size, Big Impact

Some 75 Carnegie investigators, with postdoctoral fellows and other colleagues, machinists, business administrators, facilities staff, and more contributed to some 725 papers published in the most prestigious scientific journals during the last year. Many discoveries were widely covered by the media and had extensive social media reach.

For a full listing of personnel and publications see http://CarnegieScience.edu/yearbooks
“One thing Asner discovered…was that 1 billion tons of carbon…embedded in Peruvian forests is at imminent risk of being emitted…”

GREG ASNER IN NEWSWEEK

“…two critical parts of ovulation that seem to be the same for both flies and mice.”

ALLAN SPRADLING AND JIANJUN SUN IN PHYS.ORG

“…the supernova explosion that caused the birth of our sun may have also given rise to our solar system’s rotation, allowing for the formation of the planets…”

ALAN BOSS IN THE DAILY MAIL

“…findings answer long-held questions about embryonic plant nutrition and have major potential importance for improving crop yield.”

WOLFGANG FROMMER IN SCIENCE WORLD REPORT

“A new imaging tool… allows researchers to study the dynamic of growth of root systems in soil and uncover the molecular signaling pathways…”

JOSE DINNENY IN AGROFESSIONAL WEEKLY

“Some minerals may have helped early organisms emerge.”

ROBERT HAZEN IN WIRED

“The quasar, the brightest ever detected in the early universe, was found…”

YURI BELETSKY IN THE GUARDIAN

“Basically the storms that we should’ve had in California ended up whacking New England.”

CHRIS FIELD IN THE WEATHER CHANNEL

“A missing link to the 1930s theory of metals proves that thermal convection drives the Earth’s magnetic field.”

RONALD COHEN IN THE INTERNATIONAL BUSINESS TIMES

“Panel urges research on geoengineering as a tool against climate change.”

KEN CALDEIRA IN THE NEW YORK TIMES

“Mysterious radio burst captured in real-time for first time ever.”

MANSI KASLIWAL IN THE HUFFINGTON POST

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Carnegie Investigators

THE GEOPHYSICAL LABORATORY

Matter at Extreme States, Earth/Planetary Science


THE DEPARTMENT OF EMBRYOLOGY

Genetics/Developmental Biology


Carnegie Investigators

Research Staff Members

ALEX BORTVIN
DONALD D. BROWN, Director Emeritus
CHEN-MING FAN
STEVEN A. FARBER
JOSEPH G. GALI
MARNIE E. HALPERN
ALLAN C. SPRADLING, Director
YIYAN ZHENG
Staff Associates

CHRISTOPH LEPPER
ZHAO ZHANG

From November 2014
The Observatory » Astronomy


*Visitors/Students
THE DEPARTMENT OF PLANT BIOLOGY

Plant Science

A Gift for the Future

One of the most effective ways of supporting the work of the Carnegie Institution is to include the institution in your estate plans. By doing so, you can support cutting-edge, independent scientific research well into the future.

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