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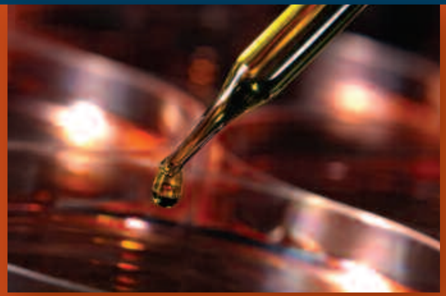

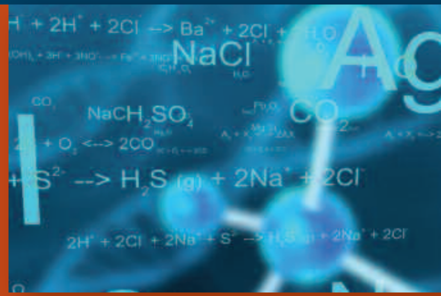

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Design by Tina Taylor, T2 Design
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ISSN 0069-066X

2006-2007 YEAR BOOK

CARNEGIE INSTITUTION OF WASHINGTON

Carnegie Institution
OF WASHINGTON

2006-2007

YEAR BOOK

Department of Embryology

Geophysical Laboratory

Department of Global Ecology

The Carnegie Observatories

Department of Plant Biology

Department of Terrestrial Magnetism

First Light & CASE

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Las Campanas Observatory	Casilla 601 / La Serena, Chile	
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2006-2007 YEAR BOOK

The President's Report

July 1, 2006 - June 30, 2007

CARNEGIE INSTITUTION OF WASHINGTON

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About Carnegie

"... to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind ..."

The Carnegie Institution of Washington 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.

Carnegie Institution

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The President's Commentary

Preparing for the Future

Carnegie president
Richard A. Meserve
(Image courtesy Jim Johnson.)

Andrew Carnegie's goal in establishing the institution was to advance scientific understanding by finding exceptional scientists and providing them with the means to pursue highly original work. This formula has proven highly successful; in each of our departments, we are accomplishing remarkable cutting-edge research. This reality is demonstrated by the coin of the scientific realm—the large number of articles published by our staff in prestigious peer-reviewed journals (see pages 72-87). It is also demonstrated by the recognition achieved by our scientists in the last decade—a Nobel Prize, three Balzan Prizes, a Lasker Prize, three Gruber Prizes, a Louisa Gross Horwitz Prize, the Lehmann Medal, the Dana Medal, and many others.

To prepare for the future, we should build on our demonstrated success and pursue a cluster of complementary goals:

Maintain the diversity of Carnegie science across our existing departments.

Carnegie supports a diverse range of scientific disciplines. All of our departments are vital and, I believe, have had impacts on scientific knowledge that are disproportionate to their sizes. This perspective is reinforced by my interactions with outside scientists and by the periodic, careful departmental reviews that are undertaken by visiting committees. As a result, each department deserves continuing support. We should not shift substantial resources away from one to grow or benefit another.

Retain departmental flexibility to define and pursue scientific opportunities.

The scientific opportunities in given fields wax and wane over time. Carnegie has managed this reality by allowing the focus in each department to evolve. Perhaps the Department of Terrestrial Magnetism (DTM) provides the clearest example. Although it once investigated the subject indicated by its name, no serious work in that field has occurred for almost 80 years. The fundamental Carnegie guidance to allow substantial freedom to individual scientists to pursue research that promises significant advances has resulted in significant shifts in focus over time.

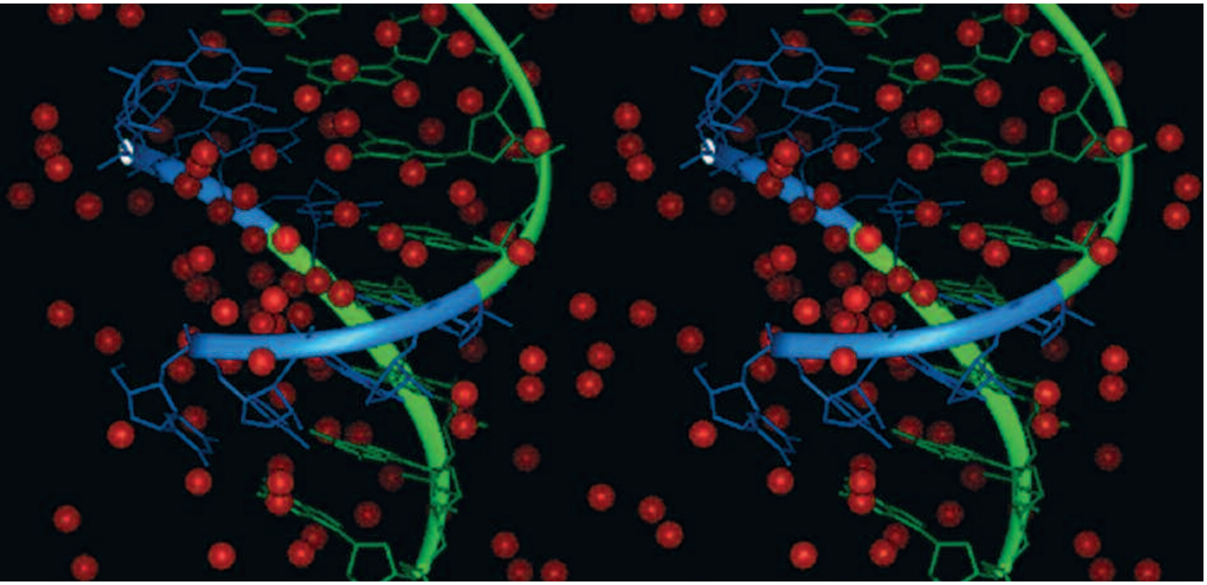
The preservation of this capacity to adapt implies a strategy of seeking, in the main, to avoid top-down direction of scientific activities. Rather, the institution should respond to the special opportunities for significant advances that are identified by individual scientists or departments. Because of the need to preserve core support of all departments, the financial capacity for change arises chiefly from funds that are redirected within individual departments, that are available at the margin, or that arise from support from government agencies, foundations, or individuals. Changes in departmental direction also arise through the appointment of new scientific staff, and the department directors play a critical role in these decisions.

Joe Gall at the Department of Embryology has been awarded numerous prizes over the years. The Lasker Foundation awarded him the prestigious 2006 Lasker Medical Research Award for Special Achievement in Medical Science as "a founder of modern cell biology who has made seminal contributions to the field of chromosome structure and function, who invented in situ hybridization, and who has been a long-standing champion of women in science." Gall was also chosen to receive the 2007 Louisa Gross Horwitz Prize, awarded annually by Columbia University to recognize outstanding contributions to basic research in the fields of biology and biochemistry. Gall shares the 2007 award with Elizabeth H. Blackburn of the University of California, San Francisco, and Carol W. Greider of the Johns Hopkins School of Medicine.

Provide an exceptional research environment.

Attracting exceptional people to our scientific staff and providing an environment in which their research can flourish involves several components:

- Provide our scientists with freedom to define their own research agenda, and strive to minimize barriers that inhibit productive research.
- Ensure competitive salaries for both scientific staff and specialized support staff.
- Maintain the vibrancy of the research environment with high-quality postdocs. Postdocs are a means to propagate Carnegie's special skills to the scientific world and to strengthen the connectivity of our staff to the broader scientific community.
- Ensure that equipment and instrumentation needs are met. The ordinary budget process, guided by priorities established by the department directors, has in the past limited equipment support too severely. We are now analyzing equipment requests, with the target of allocating 6-8% of our budget for equipment.



Carnegie and the University of Massachusetts hold the patent to RNA interference (RNAi). RNAi is a powerful tool in which double-stranded RNA suppresses the activity of specific genes. It was discovered by Andrew Z. Fire while he was at Carnegie's Department of Embryology and Craig Mello of the University of Massachusetts Medical School. They shared the 2006 Nobel Prize in Physiology or Medicine for this discovery. RNAi is used to conduct research and to develop products to combat diseases such as cancer and HIV.

(Image courtesy IMB Jena Library of Biological Macromolecules.)

Preserve and enhance the institution's financial base.

The Carnegie endowment enables the fulfillment of our mission: it allows our scientists to pursue more risky, more novel, or more long-range research than can typically be supported with outside funding. Fortunately, as a result of the considerable skills of our Finance committee and the generosity of our donors, we have been highly successful in the management of the endowment. It is now $450 million larger than if we had simply kept pace with inflation over the past 15 years. Careful efforts to invest the endowment prudently to maximize return consistent with reasonable risk have been and must remain a continuing high priority.

We must balance the use of the endowment to satisfy current needs against the obligation to meet the needs of future scientists. The fundamental discipline for achieving this balance is careful adherence to our spending rule.[1] This discipline should be maintained, while recognizing that a special need may occasionally arise that justifies an expenditure in excess of that allowed by the spending rule.

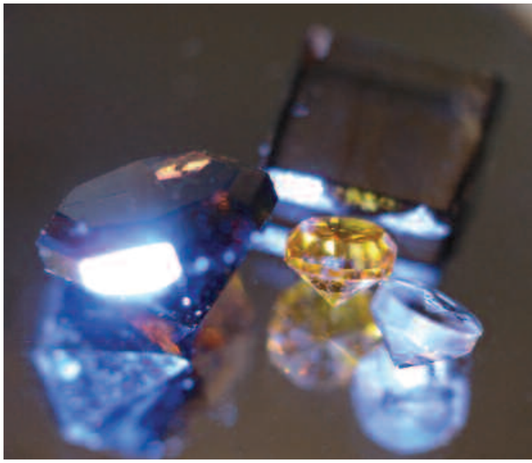
To stretch our endowment dollars, it is appropriate for Carnegie scientists to seek outside funds (federal and private) to support our research. Because of the

[1] *The spending rule provides for the allocation of funds from the endowment to meet current needs that is defined as the sum of 70% of our most recent budget and 1.5% (5% of 30%) of the value of the endowment at the end of the most recent fiscal year, less an allowance for debt obligations. The allocation is examined on a yearly basis by the Budget and Operations committee.*

varying availability in funding across scientific fields, there are differences in the proportion of each department's budget that arises from outside funding. For example, our optical astronomers are typically less well supported from federal dollars than are our plant biologists. Hence we must accept the reality that some departments may be more dependent on the endowment than others.

In this connection, it is important to ensure that reliance on outside funds does not distort the work that is undertaken. That is, outside support should be sought solely because of the intrinsic merit of the scientific work, not simply to obtain additional money. The department directors play an important role in ensuring that outside funding facilitates worthwhile scientific work consistent with our mission.

The enhancement of the institution's financial capacity requires modernization of our development activities. Carnegie faces certain challenges in this regard because, unlike a university, we do not have a natural constituency—an alumni body—that can serve as the base for fund-raising. Moreover, Carnegie's purpose—to advance basic science—may not have the widespread appeal that solving a pressing societal problem or curing a human disease may present. Carnegie-type science will yield paradigm-shifting advances that can open whole new means for addressing human problems, but such gains cannot be promised in connection with individual projects. Hence our appeal must be to a unique constituency with the means to provide significant support and the vision to value our work.



The diamond-making team at the Geophysical Laboratory developed a chemical vapor deposition process to produce large, superhard diamonds very quickly. The crystals are important in high-pressure research; they are used to create extreme pressures.
(Image courtesy Russell Hemley.)

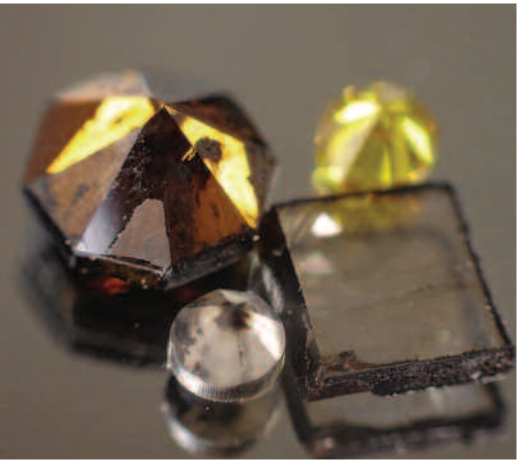
Carnegie has been effective in recent years in approaching foundations that support basic science. We now are also building a development capacity to establish enduring relationships with a broad group of individuals. This work has involved assembling a professional staff to provide the underpinnings for a comprehensive outreach effort and installing administrative systems to undertake broad appeals successfully. Such outside support can help us to pursue high-priority projects or to enhance the capacity of the endowment to provide enduring financial support.

Similarly, although the purpose of Carnegie science is not to achieve commercial gains, we do obtain patents on commercially promising intellectual property developed by our scientists. We are pursuing a prudent and careful approach in licensing our technology to enhance these revenues. Over the past few years, the annual revenues from patents have grown from $1.8 million to $2.3 million.[2]

[2] *Major opportunities are being pursued in connection with our RNAi patent (approximately 50 licensees) and our synthetic diamond patent estate, with additional possibilities arising from certain recent work at Plant Biology (FRET technology).*

Pursuing the various goals described here will require more resources than reasonably can be expected from our endowment. Nonetheless, I believe that the various means to supplement endowment support should enable us to achieve our goals.

Recognize special opportunities.



Carnegie must ensure a continuing capacity to respond to special opportunities or needs that have the potential to lead to major scientific breakthroughs or that are essential to the future of a department or the institution. Several examples are now before us:

- We live in a time of enormous scientific change arising from the convergence of astronomy, cosmology, and high-energy physics. Our astronomers view the proposed Giant Magellan Telescope (GMT) as an instrument that will allow examination of some of the fundamental mysteries of the universe. Significant efforts have been underway over several years to realize this opportunity without undue strain on Carnegie's financial capacity.
- The Global Ecology department has been remarkably successful in its first years in advancing the science of climate change, providing the foundation for the development of policy, and enhancing public awareness of the importance of this issue. There is a need to expand the activities of this department significantly, and a focused campaign to "grow" the department is being launched.
- Many of our scientists depend on advanced computational resources. For example, scientists at Global Ecology use computer clusters to run complex global circulation models and analyze large data sets from remote sensing instruments; scientists at Plant Biology maintain a massive database of genetic information on *Arabidopsis* (a mustard plant that is a model organism for plant biologists), serving scientists around the globe; researchers at DTM run complicated computer models to understand the formation of planets; and investigators at the Geophysical Laboratory use sophisticated computers to model phenomena in materials under extreme conditions (pressure and temperature). The infrastructure to support these computing needs requires refurbishment.

Make focused contributions to science education.

The District of Columbia confronts huge problems in its schools, with the result that many of the city's children are denied the opportunities that only a proper education can provide. In recognition of this need, Carnegie has contributed to its community by enhancing science education through the Carnegie Academy for Science Education (CASE). This program has been entrepreneurial in seeking support. Our Washington-based education staff is also working with colleagues in Baltimore to build a counterpart capability there. Our astronomers in Pasadena have established a mentorship program with nearby Pomona College. And now CASE is involved with some of our large federally funded projects because education and public outreach are now required components of proposals at most federal agencies.

The Department of Global Ecology's new building proclaims the department's mission of promoting a sustainable future. It was named one of the American Institute of Architects' top ten green buildings for 2007. The structure is located on the Stanford University campus and was designed by EHDD.
(Image courtesy Peter Aaron/Esto Photographics.)

Strengthen administrative operations.

With the involvement of several board members, we undertook a detailed evaluation of our business and administration systems, which resulted in sweeping recommendations for change and modernization. As part of this effort, Carnegie is installing new accounting and administrative software that will be operational by July 2008. Moreover, the business staff at headquarters has been significantly upgraded by new hires. This overall effort is very important and has had the benefit of continuing oversight by the Audit committee.

Increase the visibility of the Carnegie Institution.[3]

The Carnegie Institution has been remarkably successful in advancing scientific knowledge, but is largely unknown outside the particular scientific communities in which we work. We are often confused with other Carnegie enterprises. Our name provides no indication of what we do, and the "of Washington" modifier is fundamentally confusing because four of our six departments are elsewhere. To improve our visibility, we are promoting a new logo—Carnegie Institution for Science—and have created a new and attractive website (see www.ciw.edu/). We are issuing frequent press releases in an effort to enhance public awareness of important advances by Carnegie scientists. Our Capital Science lectures often fill our auditorium at headquarters, and we now are planning periodic symposia in New York City and California. To reach out to local communities, the Observatories staff is sponsoring

[3] *This goal bears on our efforts to enhance development as well as to recruit top-notch staff and postdocs.*

The 80,000-square-foot Maxine F. Singer Building, which houses the Department of Embryology, has 13 modern labs and striking shared spaces. It was designed by Zimmer Gunsul Frasca Partnership and built on the Johns Hopkins campus in Baltimore.

(Images courtesy Zimmer Gunsul Frasca Partnership.)

a lecture series at the nearby Huntington Library, and the Broad Branch Road departments have launched a lecture series at the handsome new auditorium in the Greenewalt Building. We believe that these activities help to create an understanding that reinforces the institution's reputation to which our scientific work entitles us.

Plan to refurbish facilities.

Some of our buildings are growing old, and renovations are needed. We have successfully completed new building projects for Embryology and Global Ecology, and we have renovated our P Street headquarters, the Observatories' building in Pasadena, and the Greenewalt Building at Broad Branch Road in recent years. Nonetheless, some of our other facilities need refurbishment, including other buildings at Broad Branch Road and at Plant Biology. Although funds are allocated each year for maintenance and upgrade of our buildings, further efforts will be required over the next decade to improve our aging properties.

Consider governance changes.

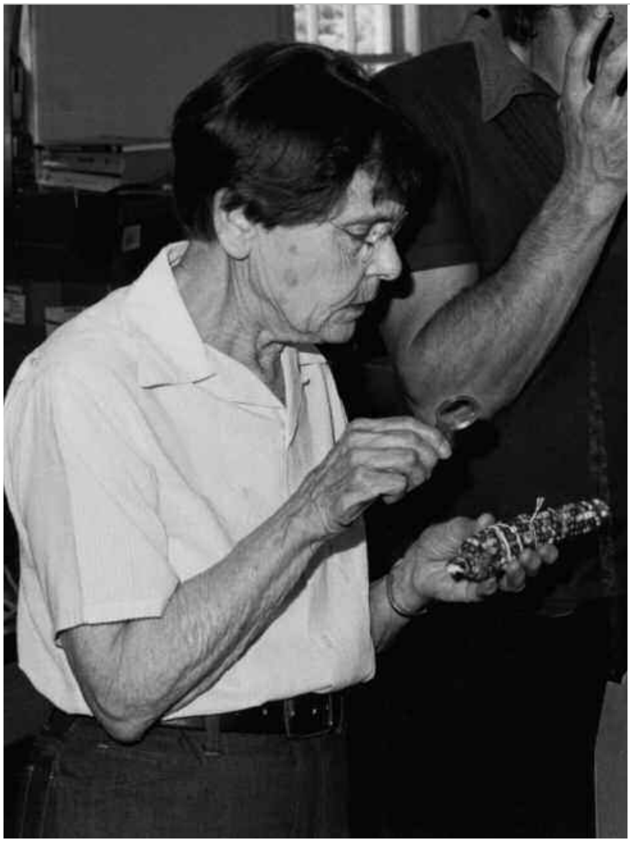
The Carnegie board plays a critical role in helping to chart the course of the institution. It is healthy to examine the effectiveness of our governance processes from time to time and to make changes as appropriate. This is a challenge that our board is confronting.

These goals provide the institution with an aggressive agenda for the coming years. The board and I believe that they build on our strengths and achievements and provide the foundation for significant scientific advances in the decades to come.

Richard A. Meserve

Friends, Honors & Transitions

Carnegie Friends



Annual Giving

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, making it possible to pursue the highly original research for which Carnegie is known.

$100,000 to $999,999

William K. Gayden
Michael E. Gellert
William R. Hearst III
Steven L. McKnight
Cary Queen

$10,000 to $99,999

Anonymous (1)
Michael Brin
Linda Brown
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Alvin E. Nashman
Deborah Rose, Ph.D.
Maxine F. Singer
Christopher T. S. Stone
William I. M. Turner, Jr.
Thomas N. Urban
Sidney J. Weinberg, Jr.
Cora Weiss

Other Annual Giving

Individuals

$1,000 to $9,999

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Henry H. Arnhold
Mary B. Bailey
Cheryl A. Bantz
Jordan Baruch
Daniel N. Belin
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Brigitte Berthelemot
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Frederick P. Woodson

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Joseph P. Ardizzi
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Richard Heckert

Richard Heckert became the chairman of E. I. du Pont de Nemours & Company in 1986, the same year he became chairman of the Carnegie board of trustees. With a Ph.D. in organic chemistry, Heckert spent his entire career at DuPont. In 1980, after being introduced to the institution by his friend and colleague, Carnegie trustee Crawford H. Greenewalt, former president and chairman of DuPont, Heckert was elected to the Carnegie board.

Heckert appreciated Carnegie's research accomplishments and traditions, but recognized the institution's need to adapt to the changing world of science. Under his leadership, the board embarked on the first capital campaign in 1989. The goal was to revitalize the scientific infrastructure and programs. With his hands-on style and dedication to research, Heckert was enormously successful in this $50 million fund-raising effort. His tireless work helped the Magellan telescope project to succeed. Other initiatives that were part of the campaign included the establishment of the Barbara McClintock postdoctoral fellowships, the Vannevar Bush Scientific Leadership Chair for the president, and, in honor of his friend, the Crawford H. Greenewalt Chair for the director of the Observatories. Even after he stepped down as Carnegie chairman in 1992, he continued to lead the campaign to its successful completion in 1996.

Heckert remained an active trustee until 1997. In addition to his distinguished fund-raising efforts, Heckert has generously supported the institution over the years. He is a member of the Edwin Hubble Society, which honors individuals who contribute between $1 million and $10 million to Carnegie during their lives. The institution sincerely thanks Richard Heckert for his deep understanding of Carnegie science, his exemplary leadership, and his consistent support over the last three decades.

Foundations and Corporations

$100,000 or More

Fannie Mae Foundation
Gayden Family Foundation
Howard Hughes Medical Institute
Ambrose Monell Foundation
Gordon and Betty Moore Foundation

$10,000 - $99,999

Carnegie Institution of Canada/Institution Carnegie du Canada
Clark Charitable Foundation
The Eppley Foundation for Research
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Suzanne Nora Johnson and David G. Johnson Foundation
The Loewy Family Foundation, Inc.
The Weathertop Foundation
Sidney J. Weinberg, Jr., Foundation

$1,000 - $9,999

The Baruch Fund
Bristol-Myers Squibb Foundation, Inc.
Damon Runyon-Walter Winchell Cancer Research Fund
Samuel H. Kress Foundation
Lee and Louis Kuhn Foundation

Government

Over $1 Million

National Aeronautics and Space Administration
National Science Foundation
Space Telescope Science Institute
U.S. Department of Energy
U.S. Public Health Service

$100,000 to $1 Million

U. S. Office of Naval Research

Tom Urban

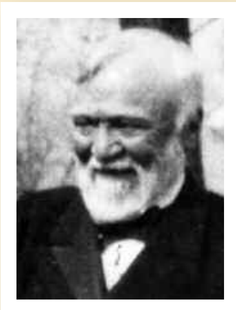
Tom Urban was chairman of Pioneer Hi-Bred—the leader in providing seeds to farmers worldwide—when he was elected to the Carnegie board in 1986. Urban took a particular interest in the Department of Plant Biology, serving on its visiting committee beginning in 1988. Although not a scientist, he was deeply interested in the institution's research. This was especially evident after Urban was elected chairman of the Carnegie board in 1992, a position he held until 2004. Urban's outlook embodies George Ellery Hale's motto to "make no small plans." He became a bold supporter of the Magellan telescope project and many other innovative Carnegie endeavors.

Urban was also a bold leader who understood the importance of the institution's emphasis on independence and originality. By opening up board meetings to department directors and others, he encouraged expression of different perspectives. For Urban, lively discussion was vital to the institution's continued success.

As chairman, Urban oversaw two important capital campaigns. The first—Carnegie Science for the City—raised $6.5 million to restore the headquarters building and support public education activities. The second—The Carnegie Campaign for Science—raised $60 million, which led to the creation of the first new department in over 80 years, the Department of Global Ecology; contributed to the construction of the Singer Building for the Department of Embryology; improved instrumentation; and bolstered postdoctoral fellowship funds, among other achievements. Leading by example, Urban issued a challenge to the board of trustees by pledging a large contribution of his own.

Over his years of service, Tom Urban has contributed generously to Carnegie science with his insight, inclusiveness, superior leadership, and gifts. He is a member of the Edwin Hubble Society. The institution is deeply grateful for Urban's continued involvement and support.

Lifetime Giving Societies



The Carnegie Founders Society

Andrew Carnegie, the founder of the Carnegie Institution, established it with a gift of $10 million. Although he ultimately gave a total of $22 million to the institution, his initial $10 million gift represents a special level of giving. In acknowledgment of the significance of this initial contribution, individuals who support Carnegie's scientific mission with lifetime contributions of $10 million or more are recognized as members of the Carnegie Founders Society.

Caryl P. Haskins*
William R. Hewlett*

The Edwin Hubble Society

The most famous astronomer of the 20th century, Edwin Hubble, joined the Carnegie Institution in 1919. Hubble's observations shattered our old concept of the universe. He proved that the universe is made of collections of galaxies and is not just limited to our own Milky Way—and that it is expanding. This work redefined the science of cosmology. Science typically requires years of work before major discoveries like these can be made. The Edwin Hubble Society honors those whose lifetime support has enabled the institution to continue fostering such long-term, paradigm-changing research by recognizing those who have contributed between $1,000,000 and $9,999,999.

D. Euan Baird
Michael E. Gellert
Robert G. Goelet
William T. Golden*
William R. Hearst III
Richard E. Heckert
Kazuo Inamori
Burton J. McMurtry
Jaylee M. Mead
Cary Queen
Deborah Rose, Ph.D.
Thomas N. Urban
Sidney J. Weinberg, Jr.

Members were qualified with gift records we believe to be accurate. If there are any questions, please call Mira Thompson at 202.939.1122.

*deceased

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 wrote in 1950, "It was Andrew Carnegie's conviction that an institution which sought out the unusual scientist, and rendered it possible for him to create to the utmost, would be worth while [sic] . . ." He further said that "the scientists of the institution . . . seek to extend the horizons of man's knowledge of his environment and of himself, in 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 and $999,999.

Anonymous (2)
Bruce Alberts
Daniel N. Belin
Brigitte Berthelmot
Donald Brown
A. James Clark
Tom Cori
Jean W. Douglas
Bruce W. Ferguson
Stephen P. Fodor
William K. Gayden
Robert and Margaret Hazen
Antonia A. Johnson
Gerald D. Laubach
John D. Macomber
Steven L. McKnight
Alvin E. Nashman
Evelyn Stefansson Nef
Vera Rubin
William J. Rutter
Maxine F. Singer
Christopher T. S. Stone
William I. Turner

Second Century Society

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

Bradley F. Bennett
Eleanora Dalton
Nina V. Fedoroff
Marilyn Fogel
Kirsten H. Gildersleeve
Robert and Margaret Hazen
Paul N. Kokulis
Gilbert and Karen Levin
Evelyn Stefansson Nef
Allan R. Sandage
Leonard Searle
Maxine F. Singer
Hatim A. Tyabji

Honors & Transitions

Honors

Trustee and astronomer **Sandra Faber** was awarded an honorary doctorate from the University of Chicago in October 2006 for her achievements on the nature of dark matter, the formation of galaxies and star populations, and early galactic evolution.

Secretary of the board **Deborah Rose** received the 2006 Yale Medal, the highest award of the Association of Yale Alumni, in recognition of her outstanding service to the university.

Carnegie trustee **Steven McKnight** was elected a fellow of the American Association for the Advancement of Science in 2006.

The National Academy of Sciences awarded Carnegie president emerita **Maxine F. Singer** the 2007 Public Welfare Medal, the academy's most prestigious honor, for her inspired leadership in science and its application to education and public policy.

President of the Carnegie Institution, **Richard A. Meserve**, was elected to the Harvard Board of Overseers in June 2007.

Embryology

Staff member **Joseph Gall** received the 2006 Senior Award from Women in Cell Biology for his scientific achievements and his long-standing support for women in science. He also received the 2007 Louisa Gross Horwitz Prize, awarded annually by Columbia University to recognize outstanding contributions to basic research in the fields of biology and biochemistry. Gall shares the 2007 award.

Department director **Allan Spradling** was awarded an honorary doctorate from the University of Chicago in 2006. He received the M. C. Chang Award in 2007 for his pioneering accomplishments in developmental and reproductive biology and genetics. He was also elected president of the Genetics Society of America for 2007.

Geophysical Laboratory

Department director **Wesley T. Huntress, Jr.**, received the American Astronautical Society's 2006 William Randolph Lovelace II Award for his contributions to space science and technology.

The American Geophysical Union awarded **Ho-kwang (Dave) Mao** the 2007 Inge Lehmann Medal for "outstanding contributions to the understanding of the structure, composition, and dynamics of the Earth's mantle and core."

Observatories

Department director **Wendy Freedman** was elected a member of the American Philosophical Society in 2007.

Astronomer **Mark Phillips** shared the 2007 Cosmology Prize of the Peter and Patricia Gruber Foundation for his role in discovering that the universe is expanding at an accelerating rate.

Plant Biology

Winslow R. Briggs was awarded the 2007 Adolph E. Gude, Jr., Award, established by the American Society of Plant Biologists and first given in 1983. It is presented triennially to a scientist or lay person in recognition of outstanding service to the science of plant biology.

Staff member **Shauna Somerville** was elected a fellow of the American Association for the Advancement of Science in 2006.


★ *Sandra Faber*


★ *Deborah Rose*


★ *Steven McKnight*


★ *Maxine Singer*


★ *Richard Meserve*


★ *Joseph Gall*


★ *Allan Spradling*


★ *Wesley Huntress, Jr.*


★ *Ho-kwang (Dave) Mao*


★ *Wendy Freedman*


★ *Mark Phillips*


★ *Winslow Briggs*


★ *Shauna Somerville*

★ *Sara Seager*

★ *Paul Silver*

★ *Vera Rubin*

★ *George Wetherill*

★ *Frank Stanton*

★ *Remi Barbier*

★ *Michael Duffy*

★ *Mary-Claire King*

★ *Russell Hemley*

Terrestrial Magnetism

Staff member **Sara Seager** was named by *Popular Science* magazine as one of its “Brilliant 10” in 2006.

Staff member **Paul Silver** was elected a fellow of the American Academy of Arts and Sciences in April 2007.

Senior Fellow **Vera Rubin** received the 2007 Award for Distinguished Achievement presented by Alumnae & Alumni of Vassar College.

Transitions

Department of Terrestrial Magnetism director emeritus **George Wetherill** died on July 19, 2006, at the age of 80.

Former chair of the Carnegie board of trustees **Frank Stanton** died on December 24, 2006, at the age of 98.

Remi Barbier was elected to the board of trustees in December 2006.

Michael Duffy and **Mary-Claire King** were elected to the board of trustees in May 2007.

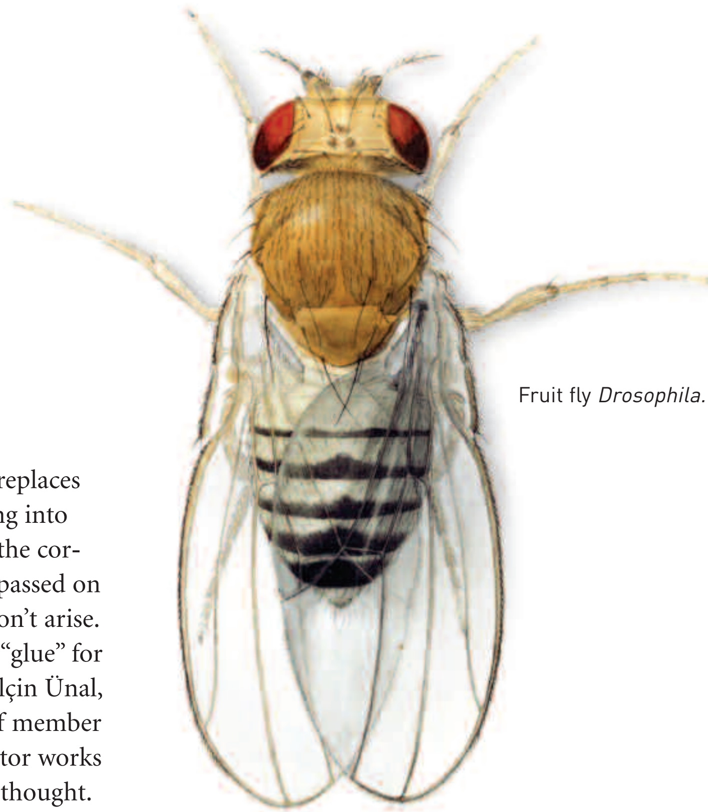
Terrestrial Magnetism staff member **Sara Seager** began an associate professor position at MIT’s department of Earth, Atmospheric, and Planetary Sciences in January 2007.

Wesley T. Huntress, Jr., stepped down as director of the Geophysical Laboratory and was succeeded by staff member **Russell J. Hemley** on July 1, 2007.

Research Highlights

Embryology

Deciphering the Complexity of Cellular, Developmental, and Genetic Biology



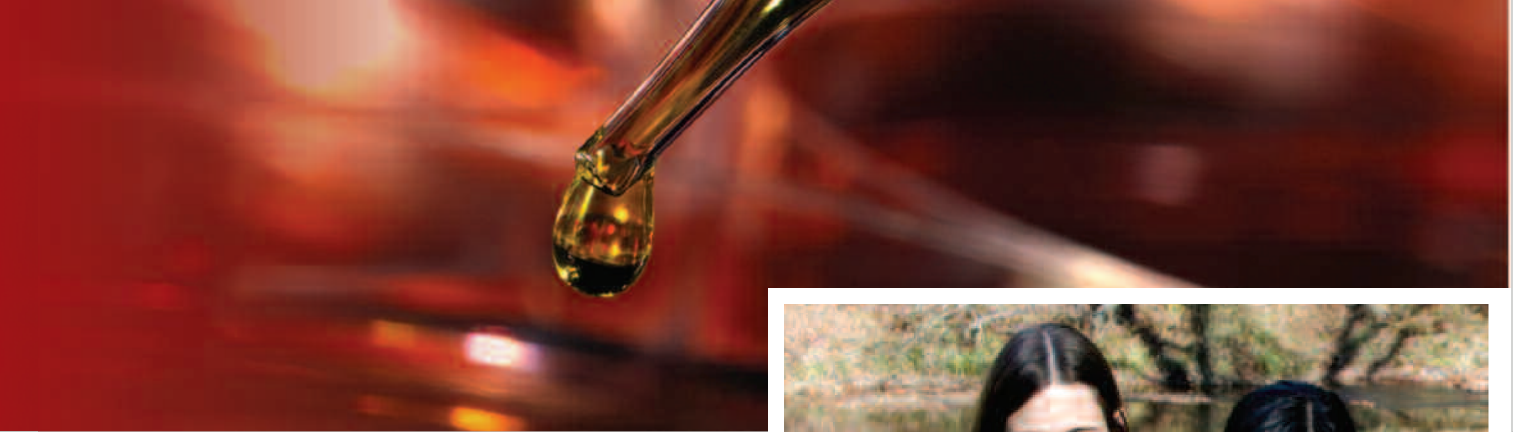
Fruit fly *Drosophila.*

The Sticky Situation with Cohesion

Over and over again, every cell in an organism replaces itself by copying its genetic material and splitting into two new cells. Proper cell division ensures that the correct number of gene-carrying chromosomes is passed on and that cancer and developmental problems don't arise. Chromosome segregation depends on a special "glue" for regulation. Recently, former graduate student Elçin Ünal, predoctoral fellow Jill Heidinger-Pauli, and staff member Doug Koshland discovered that this vital regulator works differently and more widely than scientists had thought. Their results challenge the current model of the process called cohesion, which is essential to cell division and DNA repair.

A cell has a four-phase life cycle: growth, synthesis, growth, and mitosis. During the synthesis phase, DNA inside the cell's nucleus is duplicated and two identical daughter chromosomes called sister chromatids result. To maintain the integrity of the genes, these twins must remain connected until the exact moment of separation during mitosis. A protein called Eco1 triggers a complex of other proteins, called cohesin, to keep the sisters properly glued together. Before the Carnegie study, it was believed that the process of cohesion worked only during this synthesis phase. Using budding yeast, the team found that cohesins can establish attachments between sister chromatids independent of this phase.

The last step of the cell cycle is the brief but dynamic mitosis phase. The chromosomes condense and the nucleus breaks down. Fibrous structures called spindles form, cohesion is lost, and the sister chromatids detach. The spindles help the sisters move toward opposite ends of the cell, the spindles disappear, and two new cells form.



In addition to making sure that duplicated sister chromatids stay bound, cohesion helps determine which copy is which so that the sisters are correctly distributed into the two new cells. It is also called in to repair breaks in double-stranded DNA so that damaged ends do not cause defects. Prior to this research, it was thought that cohesin was limited to binding and fixing broken ends only. But the Carnegie scientists found that when one chromosome breaks, the Eco1 protein generates cohesion-dependent attachments between sister chromatids throughout the entire genome—on unbroken areas in addition to the site of the broken DNA. This is the first evidence suggesting that Eco1 and cohesins protect chromosomes across an entire genome.

Embryology's predoctoral fellow Jill Heidinger-Pauli (left) and former graduate student Elçin Ünal (right) found that a key regulator of chromosome segregation works differently from what scientists had previously believed.

(Image courtesy Doug Koshland.)

How Stem Cells Know What to Become

Stem cells, those multipurpose precursors to other cell types, are routinely lauded for their potential to cure disease. Using intestinal stem cells (ISCs) of the adult fruit fly *Drosophila melanogaster*, former Carnegie fellow Benjamin Ohlstein and department director Allan Spradling have shown that these stem cells directly determine what type of cells their "daughter" cells should become. This research is the first to suggest that not only are these stem cells the source of new cells, but they could also be the tissue's "brains," dictating what type of new cell is needed at any given moment. The finding could transform our understanding of stem cells and potentially help fight some cancers.

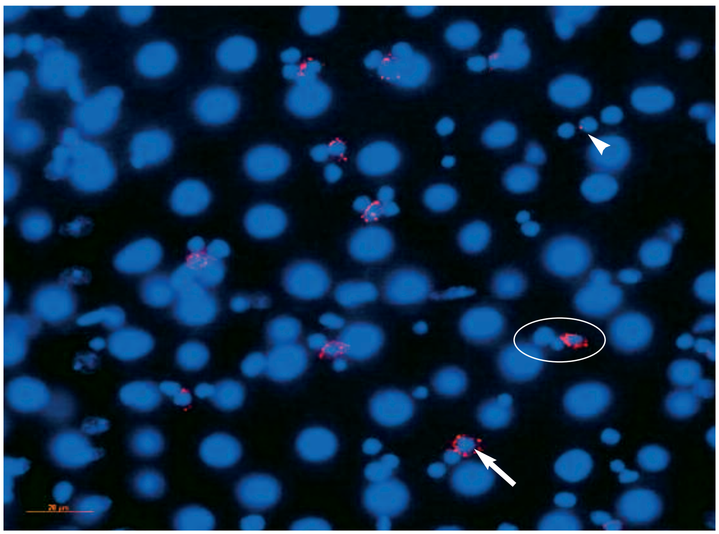
Embryonic stem cells receive a lot of attention because they can become any cell in the body. Yet adult stem

Benjamin Ohlstein (above), now an assistant professor at Columbia University, and Embryology director Allan Spradling found that stem cells in the gut of the fruit fly *Drosophila* (left page) directly determine what type of cells their "daughter" cells will become.

(Image courtesy Ben Ohlstein.)

Embryology, *Continued*

Over and over again, every cell in an organism replaces itself by copying its genetic material and splitting into two new cells.



Among the many *Drosophila* mid-gut cells (blue), only intestinal stem cells show the Delta protein (red), either at high (arrow) or low (arrowhead) levels. The strength or weakness of Delta dictates what type of gut cell the stem cell's next daughter will become. The same stem cell can change its Delta levels in response to tissue needs.

(Image reprinted with permission from Science, *vol. 315, pp. 988-992. Copyright 2007 American Association for the Advancement of Science.)*

cells are versatile too. They remain throughout life and constantly replace other differentiated cells that are lost to age or disease.

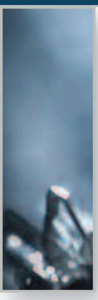
The intestinal stem cells of the adult fruit fly communicate via a signaling pathway dubbed Notch. Notch is a well-known system that communicates the need to replenish one of two cell types in the fruit fly's gut. Which type of cell a daughter will become appears to depend on a protein called Delta, which sits on the surface of the intestinal stem cell and activates the Notch pathway in the daughters.

Most daughters receive a strong Delta signal from the intestinal stem cell and become enterocytes—cells that line the inside of the gut and absorb nutrients. But when the Delta signal is weak, the daughters become hormone-generating enteroendocrine cells. For every 15 to 20 enterocytes created, one intestinal stem cell will also produce two enteroendocrine cells.

Ohlstein and Spradling tracked Delta, Notch, and several other related proteins using fluorescent marker molecules. They found that most ISCs have a lot of Delta and that Delta seems to control the types of new cells made; it also stops excessive cell division. When Delta or other Notch signaling genes were disabled, the daughter cells continued to divide, eventually producing tumors. The scientists hope that the distinctive ISC properties they found in fruit flies will help advance the study of mammalian intestinal stem cells. □

Geophysical Laboratory

Probing Planet Interiors, Origins, and Extreme States of Matter

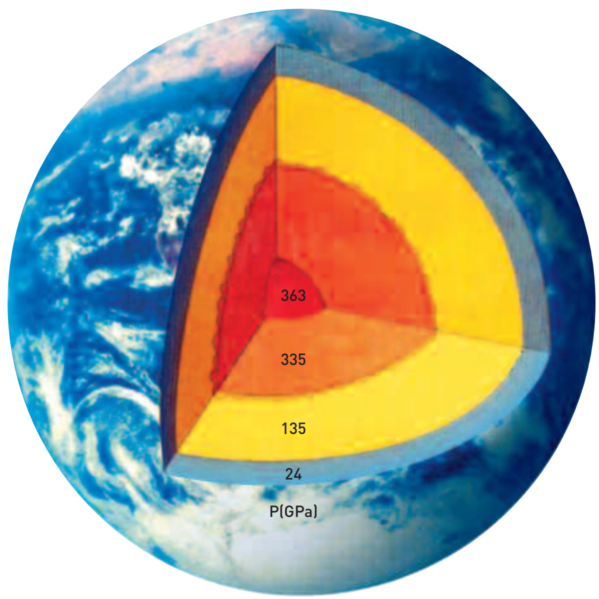


High-Pressure Observatories on New Worlds of Matter

Advanced observatories open our eyes to unknown worlds. For two decades, the Geophysical Laboratory (GL) has operated unique high-pressure observatories at synchrotron facilities such as the National Synchrotron Light Source (NSLS) in New York and the Advanced Photon Source (APS) in Illinois. Dedicated programs such as the High Pressure Collaborative Access Team (HPCAT) beamline observatory at the APS and the newly launched High Pressure Synergetic Center (HPSynC) led by Ho-kwang (Dave) Mao and Russell Hemley have yielded streams of discoveries in the vast new worlds of compressed matter.

At each level of compression, properties of ordinary materials are drastically altered. Fascinating new physics and chemistry prevail. Unleashing the power of high pressure, NSLS, HPCAT, and HPSynC allow scientists to tackle a range of grand challenges, from producing metallic hydrogen at low temperatures to understanding the mystery of the Earth's inner core. Tuning the pressure variable should advance our understanding of the electronic structure of materials and establish new chemical rules across the periodic table, leading to breakthroughs in mineralogy, geophysics, geochemistry, and bioscience, and to applications such as hydrogen storage, nuclear science and energy, and superhard materials.

Recently Mao and Hemley's team found that, at high pressure and under synchrotron X-ray irradiation, water molecules in ice break down into O_2 and H_2 molecules, forming a distinct crystalline phase. It is surprisingly stable and has implications for hydrogen fuel production.



High-pressure studies using the megabar diamond anvil cell developed at the Geophysical Laboratory can attain pressures equivalent to those at center of the Earth (3.6 million times atmospheric pressure). This technology has opened many avenues of research in the study of planetary interiors and novel materials.

(Image courtesy Russell Hemley.)

Geophysical Laboratory, *Continued*

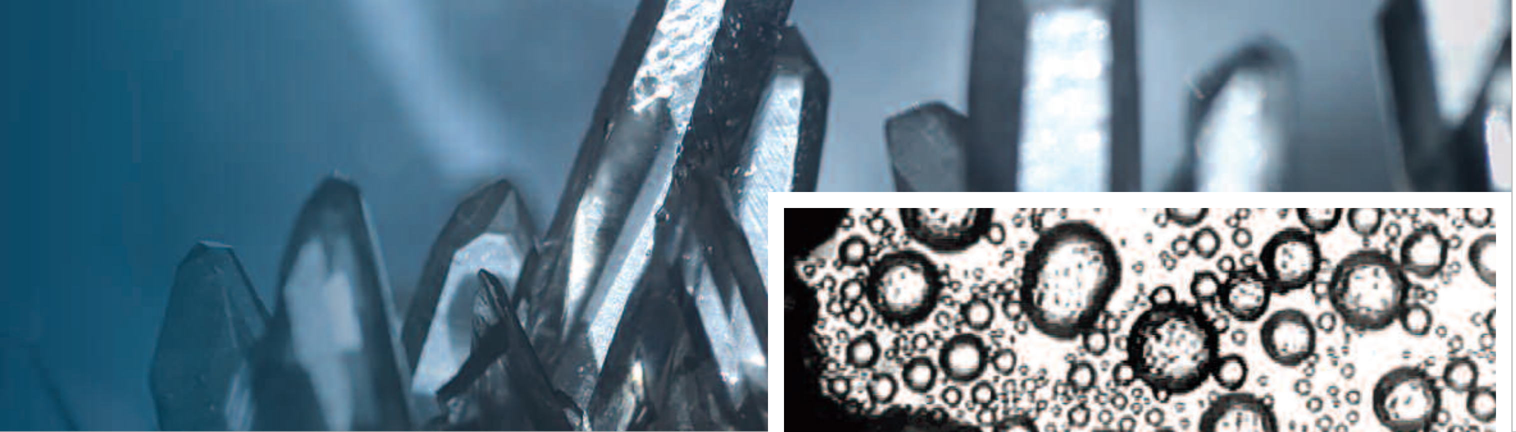
Probing minute samples at ultrahigh pressures requires high-energy beams from synchrotrons such as the Advanced Photon Source (APS) at Argonne National Laboratory. Geophysical Laboratory scientists have remained at the forefront of developing these new analytical tools.

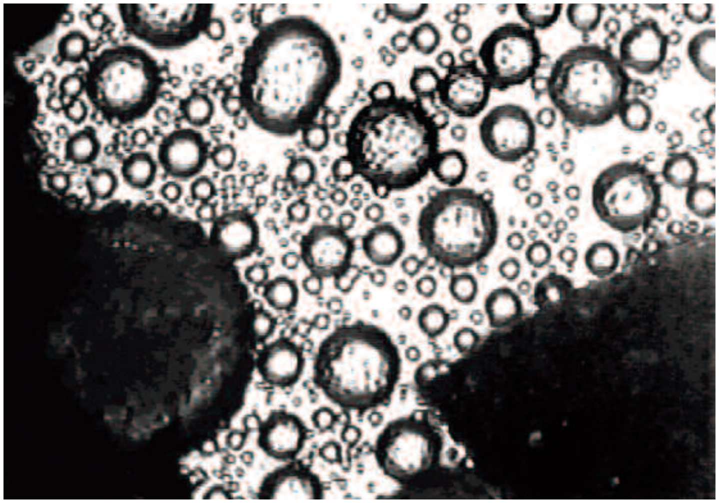
(Image courtesy Advanced Photon Source, Argonne National Laboratory.)

GL researchers also discovered that a cerium-rich metallic glass under pressure undergoes a transition that dramatically increases its density while it still remains a glass. Metallic glasses offer the potential for new materials with high strength and other useful properties, and this finding that they can exist in more than one state may lead to new, technologically useful alloys that are compositionally identical but have different properties.

The researchers also discovered that, at 600,000 times atmospheric pressure, the element vanadium undergoes a unique phase transition that involves a change in bonding but no change in density. The basis of this transition has yet to be explained but may relate to high-pressure vanadium's record-high superconducting temperature.

Experiments conducted at pressures approaching those at the Earth's outer core determined that crystals of post-perovskite, a mineral abundant there, deform more readily in some directions than others. The results can help test hypotheses regarding the enigmatic behavior of seismic waves near the core/mantle boundary.





This image shows how water-rich fluid is separated from magma under conditions similar to regions of magma storage in the Earth's interior. The water-separation process in this microphotograph helps understand the conditions that lead to explosive volcanic eruptions and associated seismic activity. Water-laden magma, or silicate melts (clear regions), are coexisting with silicate-saturated fluids (bubbles) at pressures of about 5,000 times atmospheric pressure and a temperature of 1,100°F. The material is viewed in a diamond cell; the dark grey area is a rhenium gasket. *(Image courtesy Bjørn Mysen.)*

Melts, Glasses, and Fluids in the Deep Earth

Roiling cauldrons of liquid-laden material flow within Earth's rocky interior. Understanding how this matter moves and changes is essential to deciphering Earth's formation and evolution as well as the processes that create seismic activity, such as earthquakes and volcanoes. Bjørn Mysen probes this hidden environment in the laboratory and, based on his results, develops new models that help explain the nature of this molten material and what goes on in this remote realm.

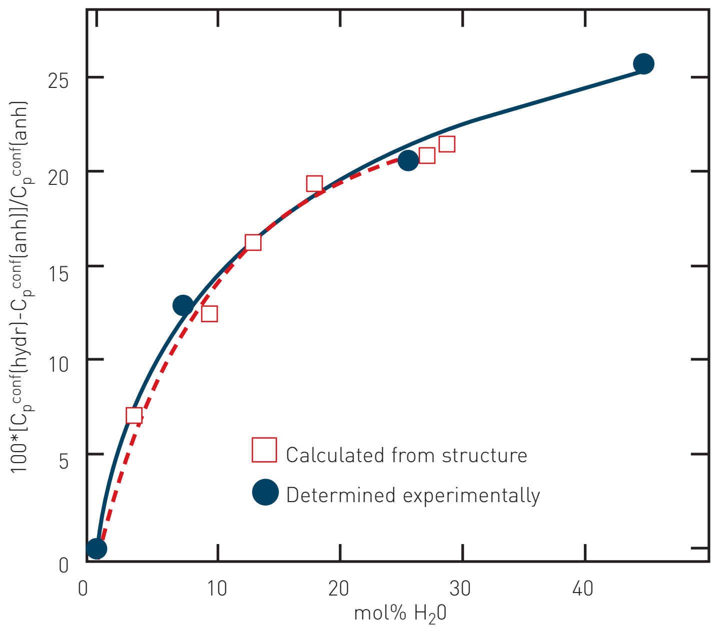
Mysen investigates changes in the atomic properties of molten silicates at high pressures and temperatures. Silicates comprise most of the Earth's crust and mantle. He uses devices, such as the diamond anvil cell, to subject melts and fluids that form silicate rocks to the conditions of the deep Earth. He uses spectroscopic technology to witness physical transformations.

The transport processes that shape the interiors of all the terrestrial planets are governed by the physical and chemical properties of silicate melts, the dominant part of magma, and certain associated water-rich fluids. Magma is formed by the partial melting of crystalline minerals. The water-rich fluids are extracted from water-laden (hydrous) minerals under high-temperature and pressure conditions. This melting and dehydration happen between 1,100°F and 2,900°F and at depths from several miles to hundreds of miles. At these depths, pressures range from about 2,000 to 100,000 times atmospheric pressure.

These melts and fluids are the principal agents for material and energy transfer within the Earth. Their viscosity and density contrast with those of surrounding crystalline materials, enabling them to travel through the crystalline matrix. The most important properties for understanding material movement are viscosity and the thermodynamics involved in material/energy exchange during melting, crystallization, hydration, and dehydration.

Mysen is currently developing structure-based property models to derive, for example, how the atomic-level structural configurations of melts and fluids—and the lower temperature glasses made from these materials—can be translated to thermodynamic information. He uses these data, in turn, to compute the necessary physical and chemical properties that characterize how magma and water-rich fluids shape our planet—the core, mantle, and crust, as well as the hydrosphere, atmosphere, and biosphere. □

Geophysical Laboratory, *Continued*

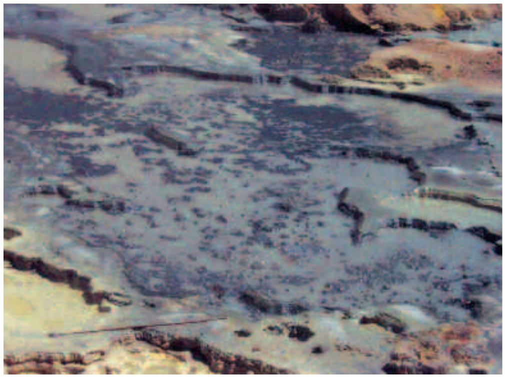


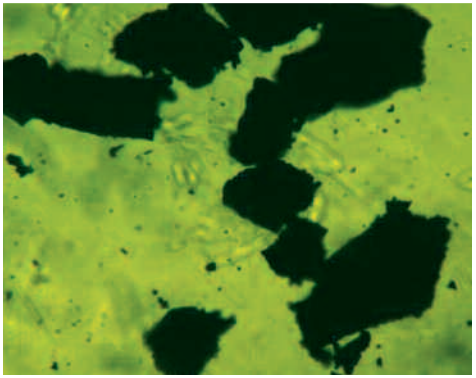
To create models that accurately reflect how high-temperature and-pressure conditions affect silicate melts and water-rich fluids in the deep Earth, Mysen conducts experiments and then uses the data to help construct models. This graph compares results from model calculations with those from experiments. It shows how the water content of magma controls its ability to retain heat (thermal energy). This information is used to model how water content affects material and energy transport properties of magma and fluids in the Earth's interior.

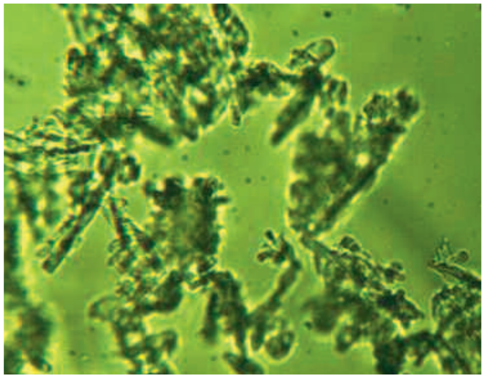
(Image courtesy Bjørn Mysen.)

The chemical building blocks of life, such as amino acids, lipids and other biomolecules, may have formed in several plausible environments on the primitive Earth, such as hydrothermal springs (below left). A more difficult question is how these compounds became concentrated from the dilute prebiotic soup. Mineral grains in the sediment such as chalcopyrite (below middle) and gypsum (right) may have acted as filters to bring together life's key ingredients.

(Images courtesy the USGS and Jim Cleaves.)







Primordial Percolations

Ever since Darwin, a key question in biology has been how life began. Darwin speculated that it might have happened in a "warm little pond" containing a broth of just the right ingredients. Research has come a long way since then, and the processes on the ancient Earth that could have formed the building blocks of life—amino acids, lipids, and other biomolecules—are relatively well understood. But generating these diverse compounds is only the first step. The primordial seas may have been awash with biomolecules, but only a fraction would have played a role in the emergence of life. How did the right molecules in this dilute soup become concentrated enough to get the evolutionary ball rolling? Staff scientist Robert Hazen and postdoctoral fellow Jim Cleaves think that the process of "geochromatography" may have played a role.

Postdoctoral fellow Jim Cleaves (right), of Bob Hazen's lab, works with summer intern Laura Kubista from St. Norbert College.

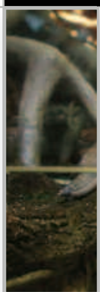
(Image courtesy Morgan Phillips.)

Chromatography is a laboratory technique used by scientists to separate different molecular species in a mixture. Molecules with different properties percolate through a specially prepared solid medium at different rates, segregating into distinct bands. Geochromatography is a natural equivalent of this process, in which the solid medium consists of mineral grains in rocks and sediments. Previous experiments have shown that the surfaces of minerals can concentrate certain organic compounds and even act like enzymes, bringing molecules together in specific ways. Perhaps it was when the water from Darwin's pond seeped into the sediment beneath that the complex chemistry of life began to take shape.

The most likely minerals to have interacted with primordial biomolecules are silicates, such as the feldspars, quartz, and clay minerals, which make up the bulk of the Earth's crust, and other rock-forming minerals such as calcite and pyrite. Hazen and Cleaves found in laboratory experiments that organic-bearing solutions flowing through powdered samples of these minerals produce bands comparable to those seen in standard chromatography. These natural materials, which would have been abundant on the early Earth, therefore have the capacity to segregate and concentrate the organic molecules from a dilute and heterogeneous mixture. More work needs to be done to see what types of compounds are segregated and how conditions like temperature and acidity affect the process. But geochromatography is a promising solution to one of the knottier puzzles in understanding the origin of life. □

Global Ecology

Linking Ecosystem Processes with Large-scale Impacts



Planting Trees Can't Substitute for Clean Energy

What could be more environmentally friendly than a tree? Trees are not just aesthetically appealing; they also provide habitats for innumerable plant and animal species. And in these times of dangerously high emissions of carbon into the atmosphere, the ability of trees to absorb and store carbon might make them appear to be the planet's salvation. Indeed, planting trees has been touted by many as an important strategy for mitigating greenhouse-induced climate change.

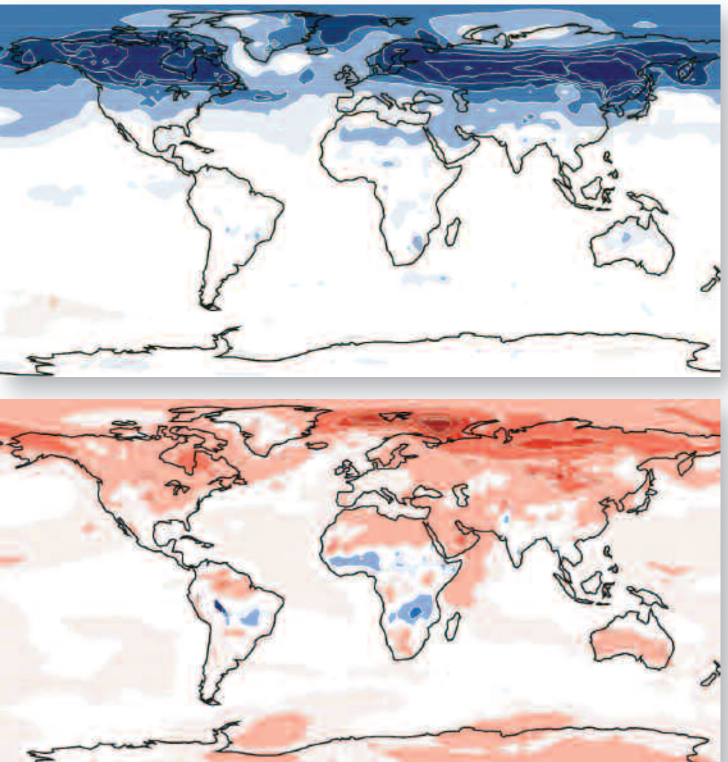
But trees don't absorb just carbon dioxide from the atmosphere; they also absorb solar energy, some of which they reradiate as heat. How much? And how do the warming and cooling effects balance out? Should we be planting or chopping trees? It's a complex problem and, like most questions regarding the global climate system, requires rigorous scientific analysis.

Global Ecology's Ken Caldeira and colleagues used sophisticated climate and carbon cycle models to compare the impacts of forested and deforested landscapes on global temperature. The models took into account both carbon cycle effects mediated by changes in atmospheric CO_2 and biophysical effects, such as moisture release and light absorption by vegetation.

The researchers found that trees are not climate cure-alls. The computer simulations indicate that trees in tropical forests live up to their reputation as climate coolers. They absorb large quantities of carbon and release lots of moisture, which in turn generates cooling cloud cover. But the simulations indicate that farther from the equator the equation adds up differently. During spring, when open ground at high latitudes can be covered by white, light-reflecting snow, dark-colored forests absorb solar energy. Forests therefore exert a warming influence, and this more than cancels out the cooling effects from carbon absorption and moisture release during the growing season.

Caldeira points out that forests are valuable even if they do not help keep the planet cool. Their benefits include natural habitat for many plants and animals, recreational opportunities for people, and sustainably harvested wood. "But the notion that we can save the planet just by planting trees is a dangerous illusion," wrote Caldeira in a *New York Times* op-ed piece. The key to preventing climate change, he emphasizes, is reducing greenhouse gas emissions from coal, oil, and gas. And solutions to this problem don't grow on trees.

Trees are not just aesthetically appealing; they also provide habitats for innumerable plant and animal species.



Computer simulations show that removing high-latitude forests (top) would cause global cooling (blue color), especially in the Northern Hemisphere where most of these forests are located. In contrast, deforestation of the tropics (bottom) would cause temperatures to rise (red), primarily because of effects on the carbon cycle.

(Image reprinted with permission from the Proceedings of the National Academy of Sciences*, vol. 104, pp. 6550-6555. Copyright 2007.)*

Diagnosing Earth's Health from the Air

An new suite of instruments aboard fixed-wing aircraft is taking Earth's vital statistics like never before. Greg Asner and team developed and now use the Carnegie Airborne Observatory (CAO) to see how our planet's ecology is faring. With its bird's-eye view, the CAO uses a waveform LiDAR (light detection and ranging) system that maps the three-dimensional structure of vegetation and combines it with advanced spectroscopic imaging, which shows the biochemistry of an area by analyzing different wavelengths of reflected light. The one-of-a-kind CAO is an unstoppable workhorse that produces stunningly beautiful 3-D maps of Earth's biochemistry from the treetops to the forest floors.

The airborne observatory flies in two modes. The Alpha system, launched January 15, 2007, can map nearly 50,000 acres per day and has a resolution of 0.3-1.0 meters. Within days of its maiden flight, Alpha mapped one of the most remote rain forests in Hawaii, revealing the extent of native and invasive species—invasives are a huge threat to the state's ecology. The data also yielded the 3-D architecture and carbon storage of every tree in the forest.

Later that same month, Carnegie and the Jet Propulsion Laboratory combined forces for the first flight of the CAO Beta system. The Beta system can fly larger regions with a more complete sampling of spectra at 2-4 meters spatial resolution, substituting AVIRIS (a NASA spectrometer) for the finer-spatial-resolution but less-sensitive spectrometer of the CAO Alpha. Its first assignment was to map dead vegetation that causes fires throughout Hawaii Volcanoes National Park. The team determined new ways to detect areas prone to fire and to predict the likely rate of a fire's spread.

Global Ecology, *Continued*

Members of the CAO group pose with their aircraft and core collaborators from the U.S. Forest Service.

(Image courtesy Paul Gardner.)

Part of the Carnegie Airborne Observatory (CAO) team make their maiden flight with the CAO Beta system. From left to right are JPL's Michael Eastwood, Carnegie team leader Greg Asner, and senior CAO team members Ty Kennedy-Bowdoin and David Knapp.

(Image courtesy Greg Asner.)

As the year progressed, the CAO Alpha and Beta systems were used in tandem to locate invasive species throughout Hawaii's Big Island and to determine the impacts of the invaders on Hawaii's last remaining rain forests.

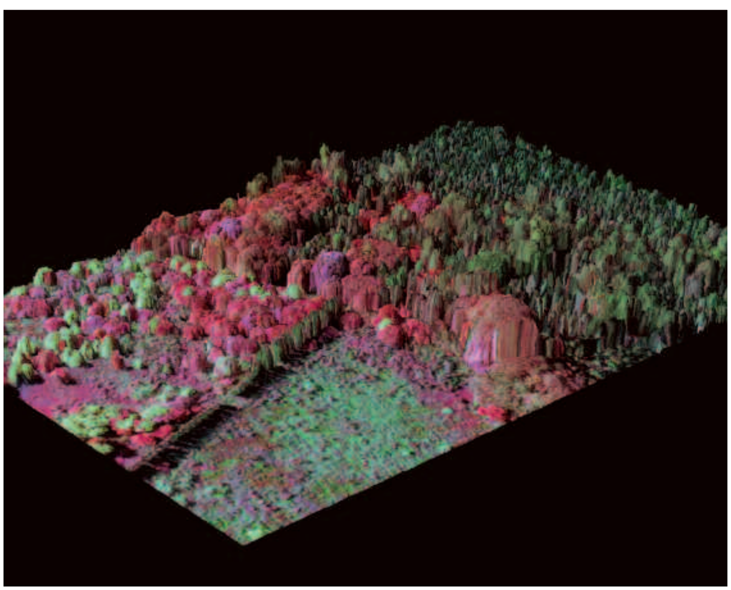
Last summer and closer to home, the team mapped San Pablo Bay, Santa Cruz Island, and the Jasper Ridge Biological Preserve at Stanford University. That mission uncovered a huge range of ecological processes, topographic features that affect erosion and plant communities, invasive species in land and aquatic environments, locations of fire fuels, and carbon storage in terrestrial ecosystems. □

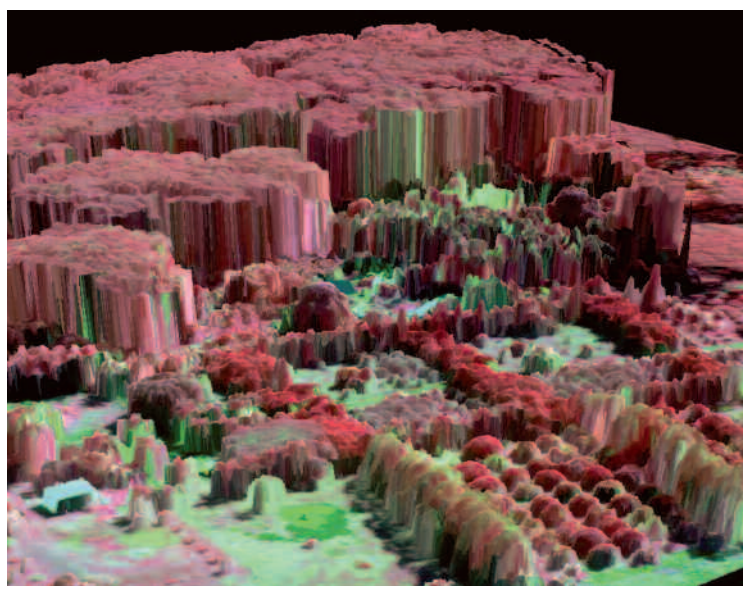
The image, below left, shows the growth rates of tree species bordering a rain forest reserve on Hawaii's Big Island. Redder colors represent faster growth rates. The red and pink colors are highly invasive trees of various species that are encroaching on the rain forest reserve boundary and the bumps are treetops. The reserve has old-growth trees with slow growth rates (in green). The invasion is coming from species in an area of managed land (former cattle pasture to the lower left).

(Image courtesy Greg Asner.)

The image, below right, shows an area with all non-native species. Some are very large trees (upper portion of the image), while others are agricultural and other non-native species of shrubs and fruit trees. All have relatively high growth rates (pinks to reds).

(Image courtesy Greg Asner.)





Observatories

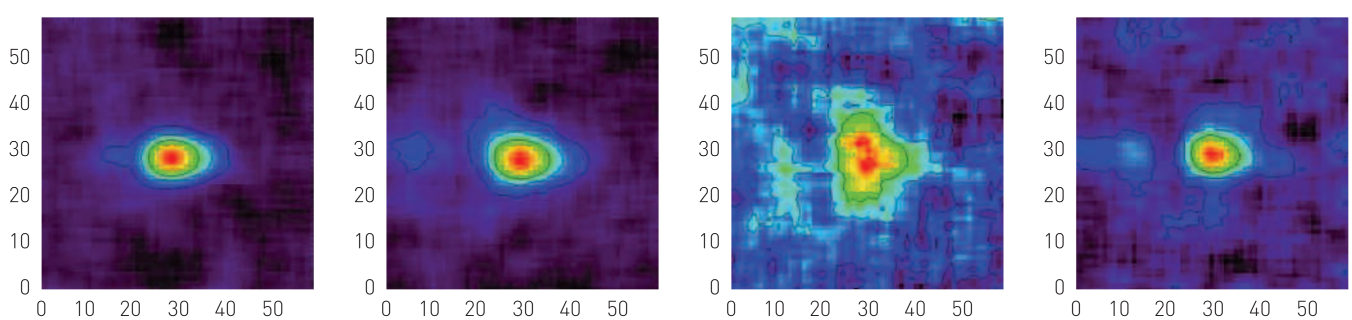
Investigating the Birth, Structure, and Fate of the Universe

Exposing the Building Blocks of Galaxy Formation

The farther astronomers look into space, the farther they see back in time, thus tracing the evolution of the universe. It is generally believed that the universe in its infancy was filled with a thin, almost homogeneous gas. A popular theory of galaxy formation, the "hierarchical picture," predicts that the gas accreted, forming smaller objects, which then collided and merged to become the massive objects seen today.

This theory recently got a boost when staff astronomer Michael Rauch, postdoctoral fellow George Becker, and colleagues undertook an ultradeep search—using the European Southern Observatory's Very Large Telescope—for intergalactic gas and galaxies when the universe was only 15% of its present age. This survey was the most sensitive one ever undertaken for such distant galaxies. The researchers found a new population of faint protogalaxies—the likely building blocks of today's galaxies, such as our Milky Way.

During the 1990s, there was mounting evidence in favor of the hierarchical picture of galactic evolution. This picture was supported by the work of Rauch and collaborators who measured distant quasars to show how the properties of cosmic gas clouds—the reservoir of matter for galaxy formation—fit within that scheme. Most of those gas clouds are dark and are visible only as foreground objects casting a "shadow" against a bright background quasar. Intriguingly, one class of these shadows—so-called damped Lyman-alpha systems—was suspected to arise when small, protogalactic building blocks

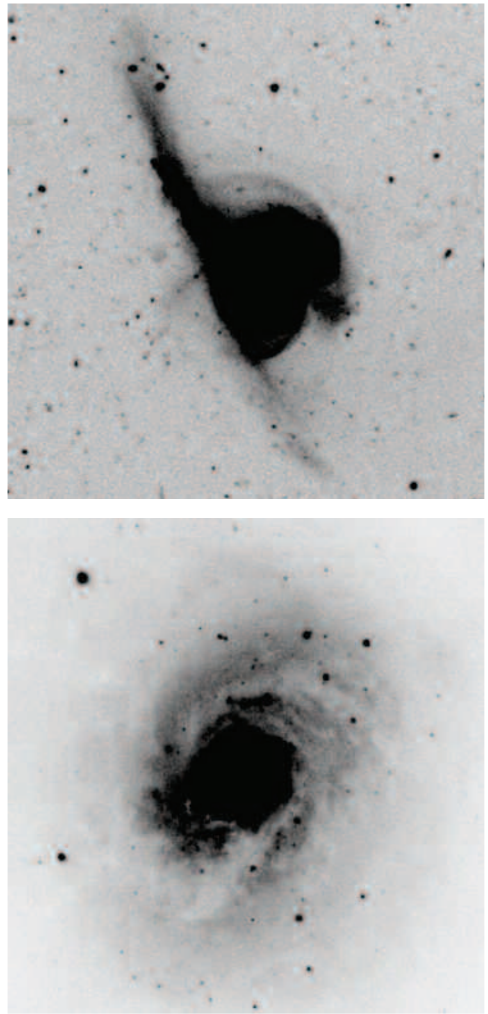


intersect the line of sight to the quasar. For many years, this was the only hint of the existence of numerous early galaxies, but until now, this possibility could not be tested because their low masses and tiny stellar populations made these protogalaxies exceedingly faint.

Rauch and his team recently tried to measure a faint intergalactic gas signal caused by the cosmic ultraviolet background radiation. But instead they found that their unprecedented 93-hour-long exposure showed dozens of faint, discrete objects emitting radiation from neutral hydrogen in the so-called Lyman-alpha line—properties predicted for protogalaxies.

The measurements imply low star formation rates and thus the immature chemical enrichment of young galaxies. The objects are about 20 times more common than all the distant galaxies previously seen from ground-based surveys—a finding consistent with the properties of the puzzling damped Lyman-alpha shadows and with the abundance of early low mass protogalaxies in the hierarchical picture.

Hydrogen atoms in distant galaxies and in the intergalactic medium absorb or release photons of light at specific wavelengths, producing characteristic absorption or emission lines when the light is dispersed into a spectrum. These are spectra of protogalaxies seen when the universe was at 15% of its present age (left). They show the Lyman-alpha emission line region characteristic of a population of low mass, weakly star-forming galaxies likely to be the building blocks of bright present-day galaxies. Michael Rauch, George Becker, and colleagues found these objects, which are about 10 times fainter than any galaxies previously seen in ground-based observations.
(Image courtesy Michael Rauch and the European Southern Observatory.)



Tidal tails (top) betray the recent merger of two spiral galaxies in the little-known remnant galaxy NGC 34, imaged with the du Pont telescope at Carnegie's Las Campanas Observatory. The Hubble Space Telescope reveals young star clusters and a new stellar disk sparkling at the center of the remnant (bottom). See page 38.
(Image courtesy François Schweizer and NASA.)

Our universe harbors billions of galaxies, with gas, mysterious dark matter, and millions to billions of stars each.

Scrutinizing Galaxy Assembly

Our universe harbors billions of galaxies, with gas, mysterious dark matter, and millions to billions of stars each. François Schweizer and colleagues study the galactic assembly process by observing nearby galaxies, focusing on how collisions and mergers reshape, grow, and evolve them. How this process happens is a central question in astrophysics today, and, for the first time, these astronomers have established a detailed (albeit tentative) sequence of events that occurs during the brief but intense merger period.

When spiral galaxies collide and merge, the rarefied gas between their stars is compressed, clumps into dense clouds and fuels an explosive birth of billions of stars and thousands of new star clusters. The phenomena that accompany these spectacular "starbursts" can be studied in the nearby universe, yielding valuable clues about galactic assembly in the distant, young universe.

Images taken with the Hubble Space Telescope and follow-up measurements from ground-based telescopes have shown that most of the turmoil during galaxy mergers lasts less than one billion years. Afterward, the restructured remnant galaxies, with their freshly minted stars and clusters, evolve more leisurely.

By studying a little-known merger remnant called NGC 34, Schweizer and colleague Patrick Seitzer, of the University of Michigan, worked out some first details. Two faint tails of tidal debris suggest the merger involved two spiral galaxies, one probably two to three times more massive than the other. Their collision likely started about 600 million years ago, when a widespread starburst lasting to about 100 million years ago began. Although the old disks of the two merging galaxies were jumbled, the remnant galaxy sports—surprisingly—a brand-new, less-than-400-million-year-old stellar disk. This disk apparently formed from gas pooled in the aftermath of the merger. Finally, a powerful gas wind, discovered fortuitously from absorption lines of sodium, began blowing from the central region. Reaching speeds of up to 1,050 kilometers per second (652 mps), the wind is likely driven by a highly obscured remnant central starburst, as well as a feeding frenzy of a nuclear black hole.

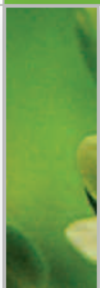
Although this detailed sequence is still tentative, Schweizer predicts that in less than a billion years, NGC 34 will come to resemble the well-known Sombrero galaxy. □

Observatories astronomer François Schweizer (above) stands atop Cerro Las Campanas, with the domes of the twin Magellan telescopes in the background. A rare cloudy day allowed Schweizer and collaborator Patrick Seitzer the leisure to hike to the top. *(Image courtesy Patrick Seitzer.)*

Schweizer thinks that NGC 34 could evolve into a galaxy similar to the Sombrero (left), a nearby spiral galaxy sporting a disk of gas, dust, and young stars within a spheroid of old stars and clusters. *(Image courtesy Space Telescope Science Institute and NASA.)*

Plant Biology

Characterizing the Genes of Plant Growth and Development




The researchers used the model plant *Arabidopsis thaliana* (left), as well as the model system yeast, to determine that neighboring pore-like structures on a cell's outer membrane must interact with each other for the cell to absorb nitrogen.

(Image courtesy Sue Rhee.)

It Takes a Group to Transport Nutrients

All cells are enclosed by a membrane that keeps important building blocks in and unwanted chemicals out. Embedded in the membrane are little machines, called transporters, which allow only certain molecules to pass. Carnegie fellow Dominique Loqué, research associate Sylvie Lalonde, fellow Loren Looger, and staff member Wolf Frommer have discovered a novel way in which these transporters work: neighbors must close their gates in synch. This mechanism was found for the transporter that takes up the essential nutrient ammonium. Frommer's group speculates that similar mechanisms are used by other transporters. Since bacteria, fungi, and humans use similar proteins, the feature probably evolved more than a billion years ago. The discovery could help in understanding human kidney disease and may be important for engineering better crops.

Plants import nitrogen in the form of ammonium from the soil. However, if too much ammonium is accumulated, toxicity results. In earlier research, the Carnegie scientists, with colleagues, were the first to identify the genes responsible for ammonium uptake. In this study, the investigators looked at how ammonium transport is regulated. They found that the end portion, or so-called C-terminus, of the protein *Arabidopsis* ammonium transporter (AMT1;1), located just below the surface of the cell membrane, acts as a switch. This arm-like feature grabs a neighboring molecule, binds with it, and changes the shape of itself and its neighbor to activate all the pores in the complex. Without this stimulus, the pores can't function. The researchers were surprised that a group effort is required, because each pore is capable of transporting nutrients by itself.

The rapid chain reaction among the different pores allows the system to shut down quickly—an advantage in surviving a toxic, ammonia-rich environment such as that encountered in Earth's early history or when an animal is marking its territory. And the system "memorizes" previous exposures to ammonium, which helps it determine when the toxicity has abated.

The scientists tried to find out what triggers the rapid shutoff. Their findings suggest it occurs by a regulatory event called phosphorylation, in which a phosphate molecule is introduced to another molecule, changing the latter and preparing it for a chemical reaction. They are now investigating how ammonium or other signals control the ON and OFF states of the transporter valve complex.

Members of the Frommer lab are shown. Top row (from left): Farzad Haerizadeh, Thijs Kaper, Hitomi Takanaga, Dominique Loqué, Totte Niittyla, Tom Eckhardt, Antoinette Sero, Kate Chabarek, Bhavna Chaudhuri. Bottom row (from left): Sakiko Okumoto, Friederike Hoermann, Wolf Frommer, Sylvie Lalonde, and Diane Chermak.

(Image courtesy Wolf Frommer.)

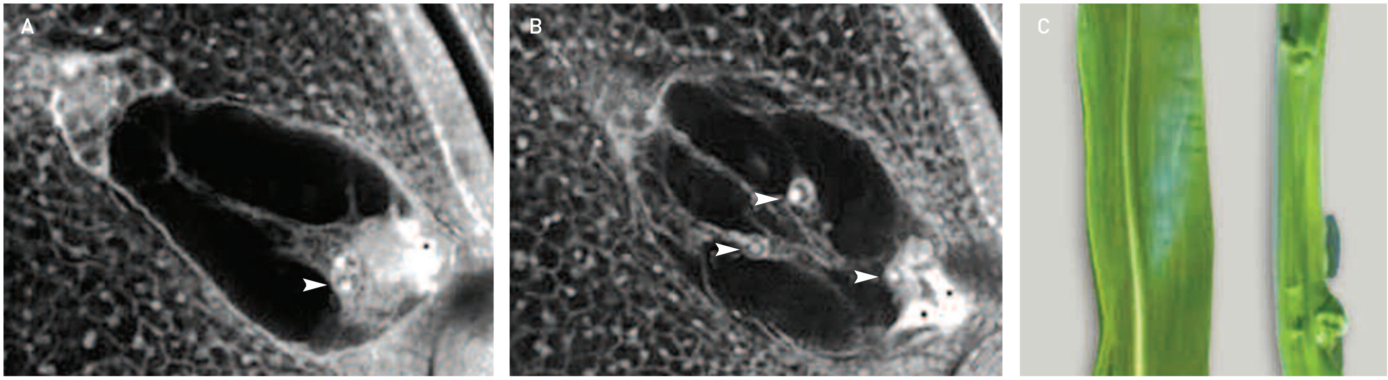
Plant Genes Bridge the Generation Gap

For all their outward serenity, plants are full of surprises—especially when it comes to reproduction. All plants have two alternating life-cycle phases: the sporophyte and the gametophyte. In some lower plants, both phases have the same form. However, in flowering plants, the gametophytes consist of just a few cells (for example, each pollen grain is one male gametophyte), while the sporophytes are the large trees, bushes, and flowers we recognize. How did this system evolve? Are there distinct sets of genes that control development of each phase, or do both phases utilize the same genetic toolbox? Matthew Evans has identified the maize *indeterminate gametophyte1* gene—*ig1* for short—and determined that it controls development of both phases of the life cycle.

Previous genetic analysis had shown that *ig1* controls female gametophyte development. Normally, the female gametophyte, called the embryo sac, consists of just a few cells, one of which ultimately becomes the egg cell. But the embryo sacs of *ig1* mutants are crammed with extra cells, including egg cells. These are often fertilized abnormally, yielding embryos carrying genes from the sperm only. This property enables plant breeders to introduce the nucleus of any desirable maize variety into the cytoplasm of an *ig1* egg cell to accelerate breeding.

Evans identified the *ig1* gene by comparing the rice and maize chromosome maps and, surprisingly, found that *ig1* also affects development of sporophyte plants. He discovered *ig1* RNA, a sign of gene activity, in young leaves and in embryo sacs, and in both it showed a similar pattern of distribution. The *ig1* gene also inhibits cell division in the leaf, just as it does in the embryo sac. The similarity between the role of *ig1* in the sporophyte and female gametophyte raises the possibility that it is an ancient gene held over from an earlier stage of evolution when sporophytes and gametophytes led separate lives. More work on the *ig1* gene's action in maize combined with similar studies in lower plants will yield exciting new insights into important features relevant for plant evolution.

Brucella has been studied extensively—one of the key reasons to pasteurize milk is to prevent infection by Brucella.



In maize, mutant *ig1* genes can affect both gametophyte and sporophyte generations. Gametophyte embryo sacs can have extra central cells (A, B), and sporophyte plants can develop malformed leaves (C: normal leaf on left and *ig1* leaf on right). This finding suggests a common developmental mechanism controlled by *ig1* in both gametophytes and sporophytes.
(Images courtesy Matt Evans.)

Plant-Like Light Sensing Found Key to Bacterial Virulence

Researchers have detected that bacteria measure light using a light sensor found first in plants. Surprisingly, scientists recently found that disease-causing bacteria need light to do their dirty work—a finding with potentially profound implications for medical treatments. Former postdoctoral researcher Trevor Swartz, director emeritus Winslow Briggs, research associate Tong-Seung Tseng, Gaston Paris of the Leloir Institute in Argentina, and other international team members are the first to study the function of plant-like, light-sensing molecules in bacteria. Their results suggest an entirely new model for bacterial virulence.

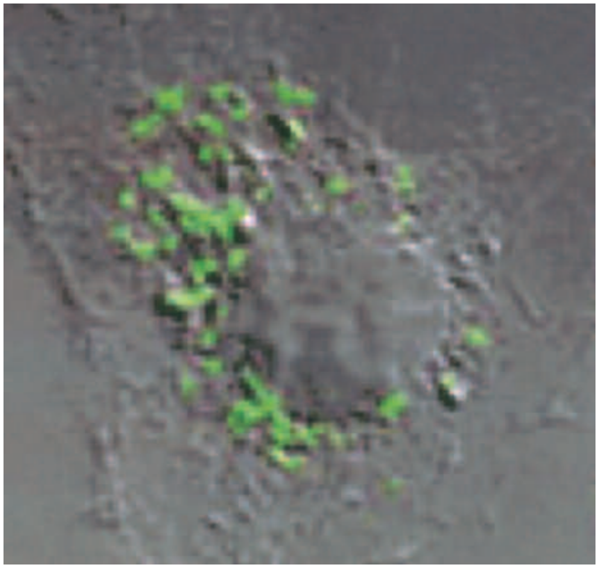
Plants developed a suite of light sensors that measure how much and which color light arrives at an individual leaf. Director emeritus Winslow Briggs was the first to identify the family of blue-light receptors that controls myriad of actions, including growth direction, leaf orientation, and chloroplast positioning. The receptors, called phototropins, use so-called LOV domains to bind the

blue-light-absorbing molecule named flavin. A LOV domain detects Light, Oxygen, or Voltage. The team was very surprised to find similar sensing domains in bacteria, which are usually thought to grow no matter whether in light or dark.

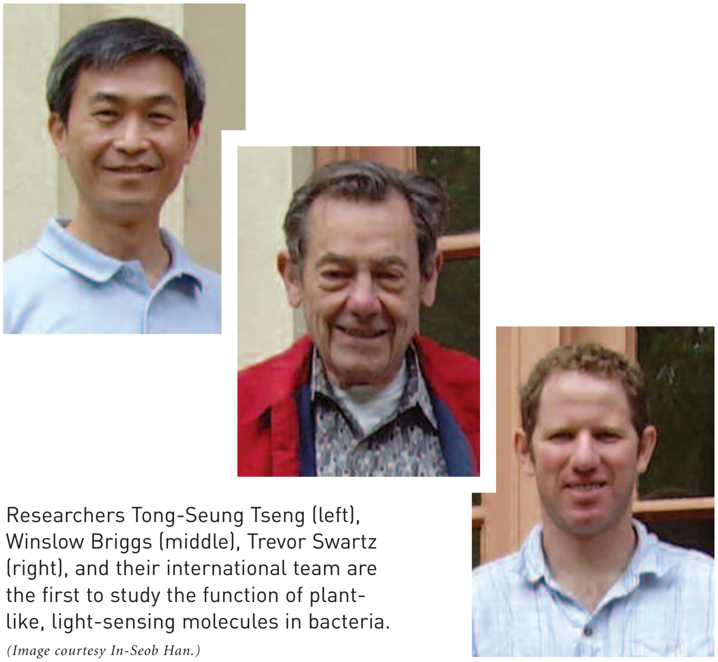
One variety of bacteria, *Brucella*, causes abortion of calves in cattle; it is known as Bangs disease and also causes illness in humans. *Brucella* has been studied extensively—one of the key reasons to pasteurize milk is to prevent infection by *Brucella*.

Many bacteria have signaling proteins involved in a cell's response to stimuli that are similar to light-sensing proteins in higher plants. The sensors in the bacteria are closely related to phototropins. LOV-domain proteins have been found in more than 100 different bacteria. The researchers looked at four species. When they disabled the LOV gene in *B. abortus*, its virulence—the ability to reproduce enough to cause disease—dropped to less than 10% of that of normal bacteria. In another simple experiment, the team found a similar drop in virulence, indicating that *B. abortus* depends on sunlight to wreak havoc.

The researchers discovered that bacterial LOV domains activate a common signaling pathway that begins with a class of proteins called histidine kinase, which transmit signals for the cell to adapt to changing environmental conditions, such as nutrients or toxic substances. This work is the first ever to demonstrate a light-activated histidine kinase in a bacterium and show that it plays an essential role in its virulence. □



This fluorescence micrograph shows *Brucella abortus* bacteria (green) replicating in an immune-system cell.
(Image courtesy Jean Celli, NIH.)



Researchers Tong-Seung Tseng (left), Winslow Briggs (middle), Trevor Swartz (right), and their international team are the first to study the function of plant-like, light-sensing molecules in bacteria.
(Image courtesy In-Seob Han.)

Terrestrial Magnetism

Understanding Earth, Other Planets, and Their Place in the Cosmos

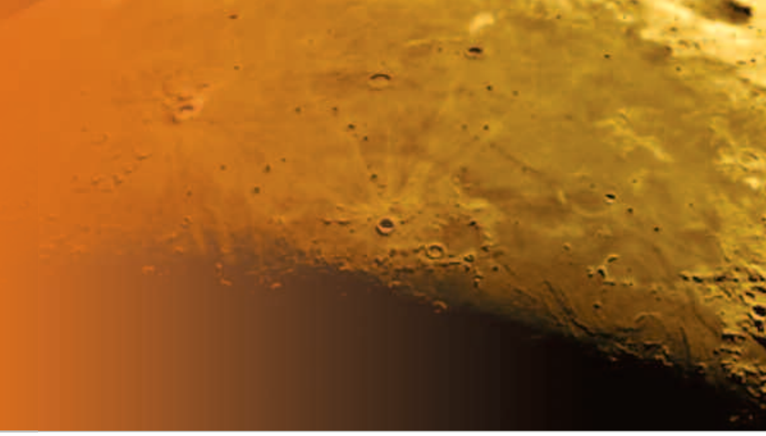
A Shocking Start for the Solar System

Astronomers hypothesize that during its birth from a rotating cloud of gas and dust, our Solar System may have needed an extra kick from a nearby stellar explosion. The gravitational collapse of an isolated presolar cloud cannot account for some details of the isotopic composition of the Solar System. Staff member Alan Boss is using sophisticated computer models to understand our Solar System's origins.

Studies of primitive meteorites have shown that the Solar System formed from a disk of gas and dust laced with iron-60 (^{60}Fe) and aluminum-26 (^{26}Al) atoms. These unstable isotopes, with half-lives of 1.5 and 0.7 million years, respectively, were created in the belly of a massive star that exploded as a supernova, spewing the newly formed isotopes out into the wake of its expanding shock front. To explain how these short-lived isotopes could have been incorporated into meteorites, astronomers have proposed that the supernova shock wave may have smacked into a dense cloud of gas and dust, injecting some of the isotopes into the cloud and triggering it to collapse due to its own gravity. As the Solar System formed from the collapsing cloud, a fraction of the isotopes would be included in meteorites.

While this hypothesis has been around for three decades, it was only in 1995 that Boss published the first detailed models of how the shock front could simultaneously trigger collapse and inject isotopes into the cloud. To achieve the high-resolution models needed for this study, Boss and his colleagues are now using the "FLASH" state-of-the-art hydrodynamics code developed at the University of Chicago. FLASH uses a procedure called adaptive mesh refinement, which allows the code to automatically increase its spatial resolution in regions where it is necessary, such as shock fronts, and to decrease the resolution where it is not. FLASH thus provides a much higher-resolution picture of how the triggered injection process works than was possible with the codes Boss used in the past. These higher-resolution calculations reveal details of the collapse and injection process on much smaller scales than the previous work, perhaps allowing the injection fingers to be followed down to the scale of the Solar System itself.

Cross sections show the simulated presolar cloud at the moment a supernova shock front first impacts the cloud (left image), and about 0.1 million years later (right image), when the shock front is beginning to compress the cloud to the point it collapses to form the Solar System. The initially spherical cloud is assumed to be symmetric about the left-hand border of the image. *(Images courtesy Alan Boss.)*

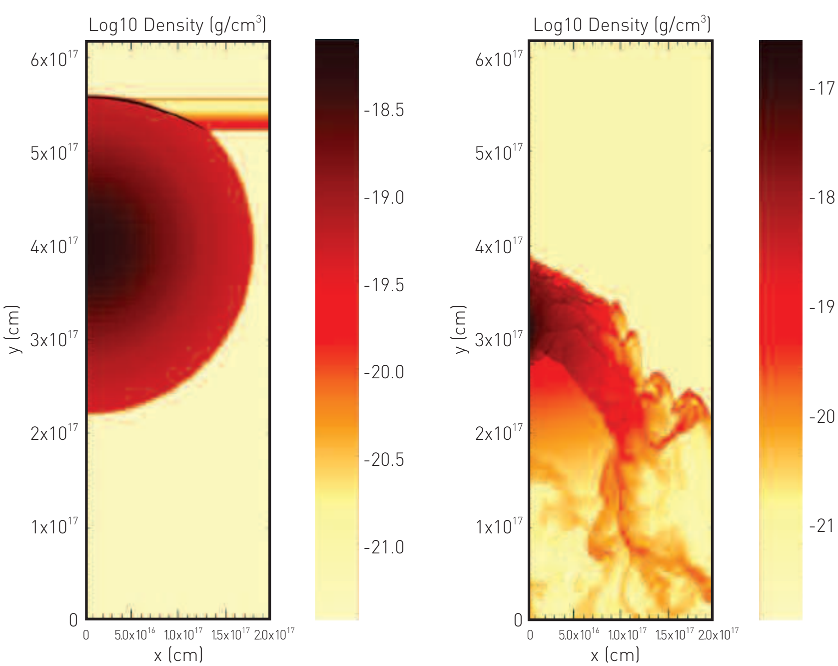


Did a Rogue Planet Cause a Lunar Cataclysm?

The Moon's large, dark basins, known as maria or "seas," were formed by huge impacts early in the Solar System's history. These impacts may have been triggered by the unstable orbit of a former planet, Planet V, which hurled asteroids toward the inner planets before plunging into the Sun or escaping the Solar System.

(Image courtesy NASA.)

Unlike the Earth, whose face is constantly being remodeled by erosion and plate tectonics, the Moon bears the scars of its earliest history. And one episode of that history may have important implications for the evolution of the Solar System. It is the so-called Late Heavy Bombardment—an interval of about 100 million years, beginning about 3.9 billion years ago, during which the Moon suffered a series of cataclysmic impacts. The results are still visible in the form of about 45 large impact basins on the lunar surface, but the cause of the bombardment has puzzled scientists for 35 years. Why was there a sudden spike in impacts 600 million years after



the formation of the Solar System, when the system should have already "cleaned up" any large, orbit-crossing debris?

Staff member John Chambers has suggested that the trigger for this event was a long-lost, fifth rocky planet, which he has dubbed Planet V, formerly occupying an orbit somewhere between Mars and the asteroid belt. Gravitational tugs from Jupiter and other planets could have destabilized Planet V's orbit early in the Solar System's history, causing it to pass through the asteroid belt and hurl asteroids toward the inner planets. Eventually Planet V would have been lost, either by plunging into the Sun or escaping the Solar System entirely, and the hail of asteroids would have ceased.

No trace of Planet V remains, of course, but Chambers was able to test the plausibility of this scenario by modeling the orbital dynamics of the Solar System with Planet V added. He found that, depending on its mass, Planet V might survive hundreds of millions of years barely disturbing the Solar System or instead might quickly wreak wide havoc, jostling the other planets to the point that Mars and Mercury would be lost. In simulations where Planet V had a mass between 10% and 25% that of Mars, the results played out in a way roughly consistent with the early bombardment scenario, especially if the initial orbits of Mars and the other surviving planets were not assumed to be the same as today. While these results can't confirm the former existence of Planet V, they indicate that the hypothesis remains a viable explanation for this puzzling episode of the Solar System's history.

Aerial photo shows the San Andreas Fault in the Carrizo Plain of central California. Earthquake waves from the 2004 Sumatra-Andaman quake weakened the fault, making it more likely to slip in the future.

(Image courtesy U.S. Geological Survey.)

It's California's Fault

The 2004 Sumatra-Andaman earthquake captured the world's attention by triggering tsunamis that killed more than 200,000 people. With a magnitude of 9.1, the earthquake had worldwide effects, some of which are still being discerned by seismologists. Staff member Paul Silver and C. V. Starr Fellow Taka'aki Taira have found evidence that the Sumatra-Andaman earthquake may have temporarily weakened North America's most famous earthquake zone—the San Andreas Fault—possibly raising odds of a seismic event. The results take seismologists a step closer to understanding how earthquakes can be predicted.

A leading hypothesis for earthquake prediction is that, immediately preceding an event, fault zones undergo either an increase in stress or a decrease in strength. But such changes require monitoring these variables at the depths in the Earth where earthquakes occur.

For 20 years seismologists have intensively studied a stretch of the San Andreas Fault near Parkfield in central California, using an array of borehole seismometers and other instruments that record all tremors and any creep along the fault. Seismograms of numerous small, repeating earthquakes have revealed that fluid-filled fractures whose seismic properties change with stress are found within the fault zone at a depth of about five kilometers. From changes in the seismograms, the researchers were able to track changes in stress on the fault.

Silver and Taira found such changes on three separate occasions from 1987 to 2007. The first was produced by a slow earthquake in 1993 (work with former postdoc Fenglin Niu), and the second by the magnitude 6 Parkfield earthquake in September 2004. But the third, in late 2004, appeared unrelated to any local disturbance.

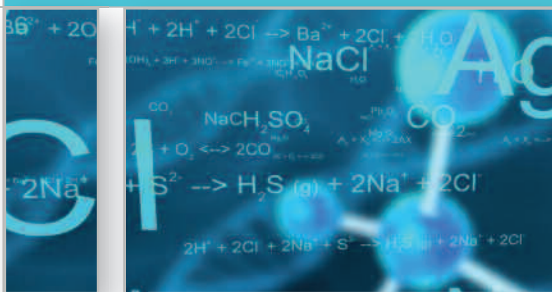
Former DTM postdoc Fenglin Niu (left), Paul Silver (middle), and collaborator Tom Daley from Lawrence Berkeley National Laboratory are at the site of a 3.5 kilometer-deep (2.2 miles) drill hole into the San Andreas fault at Parkfield, California.

It instead closely matched the timing of the December 26 Sumatra-Andaman earthquake. It was followed by an abrupt increase in the frequency of small, local earthquakes. Silver and Taira attribute the heightened earthquake activity to weakening of the fault. While the frequency of quakes increased, the size of the events decreased—a classic indicator of a weakened fault.

How did seismic waves from a distant quake cause this change? The most likely explanation is that the stress changes from the passing waves redistributed fluids within the fault zone. This served to lubricate fault surfaces, weakening resistance to movement. Whatever the mechanism, Silver and Taira have shown that it is possible to monitor stress and strength at depth on earthquake-producing faults, which is good news for earthquake prediction. □

First Light & The Carnegie Academy

Teaching the Art of Teaching Science



Teaching Real-life Science with Real Results

Fingerprinting and DNA analyses are not just the stuff of TV-programming successes. The six-week Summer Biotechnology Work Experience program of the Carnegie Academy for Science Education (CASE) introduces high school students and teachers to cutting-edge biotechnology techniques and workplace training with a unique forensics curriculum laying the foundation for real-world careers. This year some participants used their skills as interns in area labs.

In 2006 CASE was awarded a three-year grant by the Division of Undergraduate Education of the National Science Foundation to support DC Biotech: Improving Opportunities for Urban Minority Students. The program has a dual role: to bolster students' career opportunities while improving biotech workforce diversity, and teaching teachers about this important career path. CASE is the lead partner working with the Washington, D.C., Public Schools Office of Career and Technical Education, Montgomery College, McKinley Technology High School, Ballou Senior High School, and a biotech advisory committee composed of industry, research, and academic institutions.

The grassroots effort is broadening its reach. This past year, five DC Biotech students and two teachers had internships in area labs. One teacher and student worked together in the Howard University lab of Georgia Dunston, the founding director of the National Human Genome Center. They looked at the genetic aspects of asthma among African-Americans. The disease is four to six times more prevalent in this group than among Caucasians.

During the summer, 22 students from McKinley and Ballou became immersed in the six-week forensics program instructed by Julie Edmonds and Shaina Byrnes, a student from George Washington University's Master of Forensic Sciences program. At the end of each week, students independently analyzed a simulated crime scene—complete with hair samples, fingerprints, and DNA residue—using the techniques they had learned. They then argued their cases in mock trials. Meanwhile, Toby Horn rigorously prepared DC Biotech teachers for the school year ahead.

First Light, the CASE Saturday science school for middle school students, continues to blossom with laboratory investigations and field trips related to astrobiology—the

First Light, the CASE Saturday science school for middle school students, continues to blossom with laboratory investigations and field trips related to astrobiology . . .

study of the origin of life on Earth and of life's potential for existing elsewhere. Among their many activities, the students, under the instruction of mentor and teacher Guy Brandenburg, built four 6-inch telescopes and one 4½ -inch telescope to learn about the night skies and the technology behind viewing the heavens. □

A DC Biotech student (above left) explains her crime scene analysis to visitors at the summer forensics open house.

DC Biotech students (top right) dust for fingerprints as part of their "CSI" curriculum. They learn real-life science techniques that provide the foundation for careers in biotechnology.

(Bottom right) George Washington University's Ted Robinson shows summer forensics students how infrared analysis is used to analyze handwriting evidence.

(Images courtesy Toby Horn.)

Financial Profile

for the year ending June 30, 2007 (unaudited)

Reader's Note: ***In this section, we present summary financial information that is unaudited. Each year the Carnegie Institution, through the Audit Committee of its Board of Trustees, engages an independent auditor to express an opinion about the financial statements and the financial position of the institution. The complete audited financial statements are made available on the institution's website at www.ciw.edu.***

The Carnegie Institution of Washington completed fiscal year 2007 in strong financial condition due to the excellent returns 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 generous support of organizations and individuals who recognize the value of nurturing 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, 2007, the endowment was valued at over $830 million and had a total annual return, net of management fees, of 19%. During the last decade, the endowment has more than doubled, growing from $338 million to more than $830 million. Carnegie's endowment has returned an annualized 14.9% over the trailing five years for the period ending June 30, 2007.

For a number of years, under the direction of the finance committee of the board, Carnegie's endowment has been allocated among a broad spectrum of asset classes, including: fixed-income instruments (bonds), equities (stocks), absolute return investments; real estate partnerships; private equity; and natural resources partnerships. 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 finance 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 below chart shows the allocation of the institution's endowment among the asset classes it uses as of June 30, 2007.

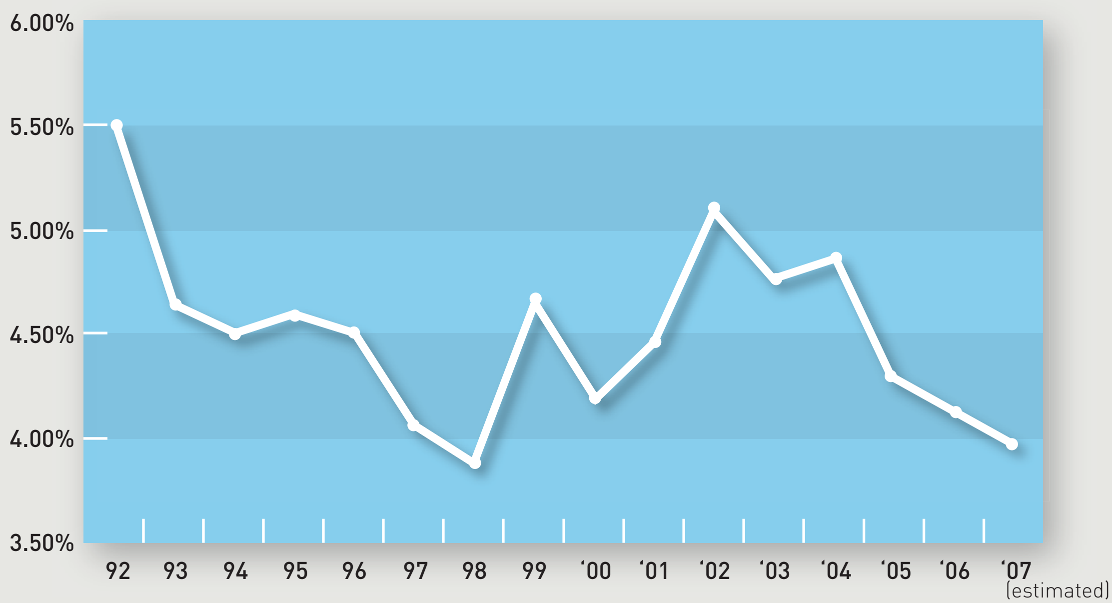
Asset Class	Target	Actual
Common Stock	35.0%	35.1%
Alternative Assets	55.0%	51.7%
Fixed Income and Cash	10.0%	13.2%

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.

Carnegie has also pursued a long-term policy of controlling its spending rate, bringing the budgeted rate down in a gradual fashion from 6+ percent in 1992 to 5.00% for 2007. For the coming year, Carnegie has revised its spending method. In the past, Carnegie determined the funds available from the endowment as five percent of a simple three-year average of year-ending endowment values. Now it follows a 70/30 rule which factors in the previous year's spending. That is, the amounts available from the endowment under the 70/30 rule is made up of 70% of the previous year's budget, adjusted for inflation, and 1.5% (5% of 30%)of the previous year-end endowment value, adjusted for inflation and for 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 15 years.

In addition to investment performance and spending restraint, Carnegie benefits from external support. 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 2007 appears in an earlier section of this yearbook. In addition, Carnegie receives important federal and private grants for specific research purposes.

Endowment Spending as a Percent of Ending Value*



*Includes debt financing expenses

Statements of Financial Position (unaudited)

June 30, 2007 and 2006

	2007	2006
Assets		
Current assets:		
Cash and cash equivalents	1,896,601	677,851
Accrued investment income	265,104	236,931
Contributions receivable	4,928,969	6,262,208
Accounts receivable and other assets	12,685,334	13,821,588
Bond proceeds held by trustee	122,106	292,688
Total current assets	$ 19,898,114	$ 21,291,266
Noncurrent assets:		
Investments	838,384,075	729,555,134
Construction in progress	4,191,109	5,590,511
Property and equipment, net	160,105,312	157,513,110
Total noncurrent assets	$1,002,680,496	$ 892,658,755
Total Assets	$1,022,578,610	$ 913,950,021
Liabilities and Net Assets		
Accounts payable and accrued expenses	10,308,534	5,513,044
Deferred revenues	34,987,592	37,305,764
Bonds payable	65,248,695	65,194,134
Accrued postretirement benefits	14,327,973	17,958,000
Total liabilities	$ 124,872,794	$ 125,970,942
Net assets		
Unrestricted:		
Board designated		
Investment in fixed assets, net	64,182,240	66,712,191
Designated for managed investment	705,600,951	603,409,368
Undesignated	45,175,534	32,507,942
	814,958,725	702,629,501
Temporarily restricted	27,990,125	30,765,782
Permanently restricted	54,756,966	54,583,796
Total net assets	$ 897,705,816	$ 787,979,079
Total liabilities and net assets	$1,022,578,610	$ 913,950,021

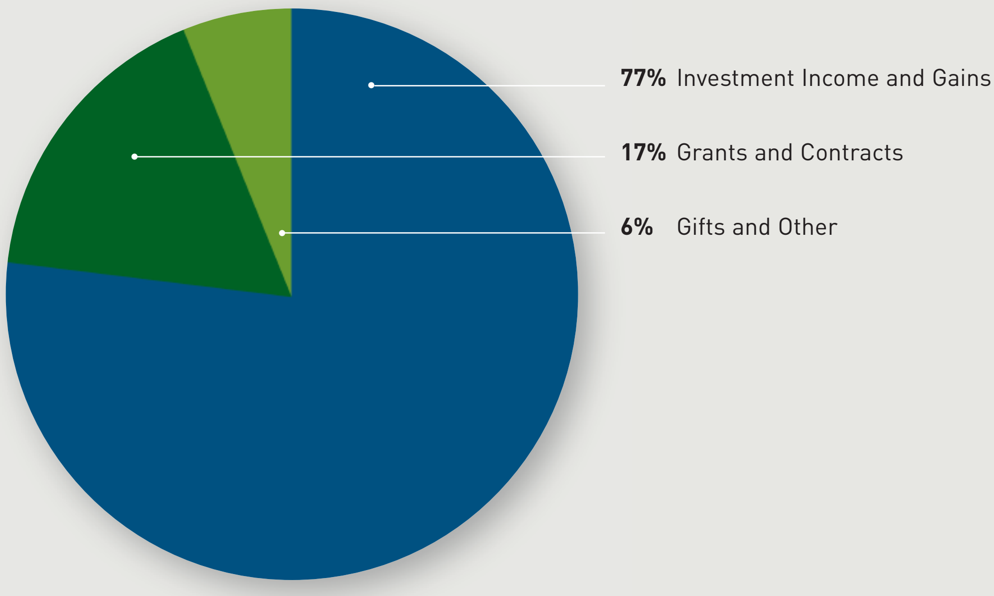
Statements of Activities[1] (unaudited)

Periods ended June 30, 2007 and 2006

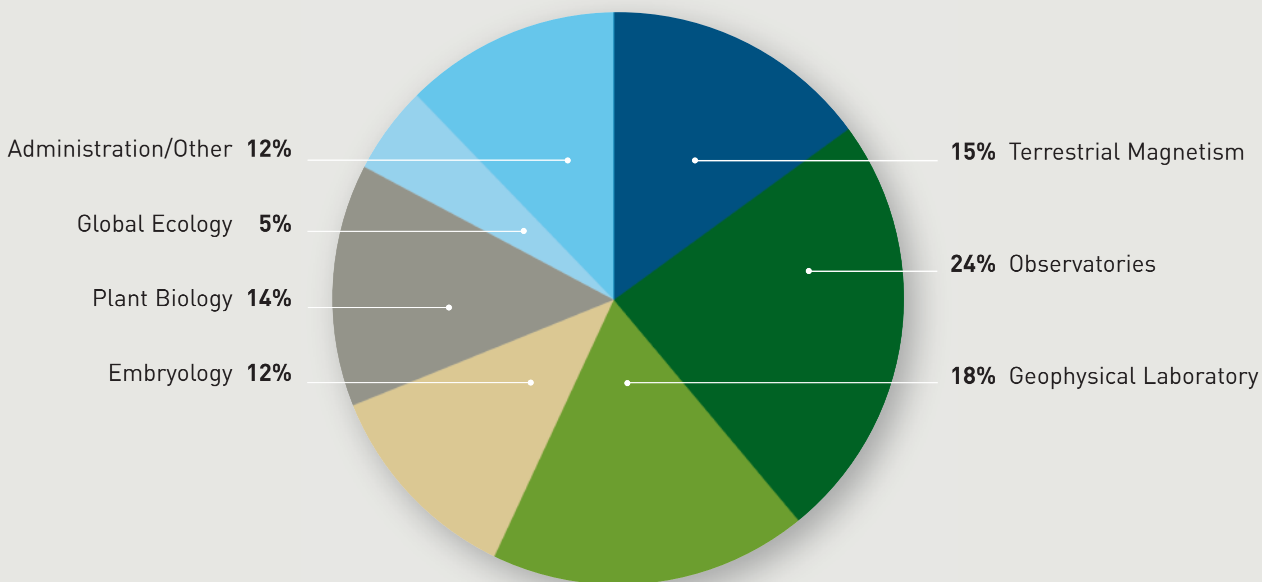
	2007	2006
Revenue and support:		
Grants and contracts	$ 31,280,089	$ 30,590,596
Contributions, gifts	4,296,626	8,384,447
Net gain or (loss) on property disposal	(22,822)	(9,290)
Other income	7,075,827	5,615,663
Net external revenue	$ 42,629,720	$ 44,581,416
Investment income	58,567,739	39,771,713
Unrealized gain	82,375,135	83,731,281
Total revenues, gains, other support	$183,572,594	$168,084,410
Program and supporting services:		
Terrestrial Magnetism	11,083,178	10,667,105
Observatories	17,816,485	21,191,344
Geophysical Laboratory	13,096,369	13,101,603
Embryology	8,635,996	10,374,852
Plant Biology	9,928,992	10,617,264
Global Ecology	3,936,862	3,801,733
Other programs	609,667	603,602
Administration and general expenses	7,967,307	8,845,515
Total expenses	$ 73,074,856	$ 79,203,018
Adoption of FASB Statement No. 158	(771,001)	
Increase (decrease) in net assets	109,736,737	88,881,392
Net assets at the beginning of the period	787,979,079	699,097,687
Net assets at the end of the period	$897,705,816	$787,979,079

[1]Includes restricted, temporarily restricted, and permanently restricted revenues, gains, and other support.

2007 Revenues and Gains ($184 million)



2007 Expenses by Department ($73 million)



Personnel

July 1, 2006-June 30, 2007

Carnegie Administration

Benjamin Barbin, *Advancement Activities Coordinator*[1]
Sharon Bassin, *Assistant to the President/Assistant Secretary to the Board*
Shaun Beavan, *Systems Administrator*[2]
Gloria Brienza, *Budget and Management Analysis Manager*
Don Brooks, *Building Maintenance Specialist*
Marjorie Burger, *Financial Manager*[3]
Cady Canapp, *Human Resources and Insurance Manager*
Ellen Carpenter, *Manager of Advancement Activities*[4]
Heather Davis, *Financial Accountant*[5]
Linda Feinberg, *Manager of Advancement Operations*[6]
Dina Freydin, *Senior Grants Accountant*[7]
Susanne Garvey, *Director of External Affairs*
Patricia Harrigan, *Financial Accountant*[8]
Darla Keefer, *Special Assistant for Administration and Building Operations*
Ann Keyes, *Payroll Coordinator*
Yang Kim, *Deputy Financial Manager*[9]
Lisa Klow, *Executive Assistant to the President*[10]
George Gary Kowalczyk, *Director of Administration and Finance*
Rhoda Mathias, *Secretary to the President*[11]
Tina McDowell, *Editor and Publications Officer*
Richard Meserve, *President*
June Napoco-Soriente, *Financial Accountant*
Michael Pimenov, *Endowment Manager*
Arnold J. Pryor, *Facilities Coordinator*
Gotthard Sághi-Szabó, *Chief Information Officer*
Christine Smith, *Chief Advancement Officer*
John Strom, *Web Manager*
Kris Sundback, *Financial Manager*[12]
Mira Thompson, *Manager of Advancement Operations*
Vickie Lee Tucker, *Administrative Coordinator/Accounts Payable*
Yulonda White, *Human Resources and Insurance Records Coordinator*
Matthew Wright, *Science Writer and Publications Coordinator*

[1] From January 8, 2007
[2] From February 1, 2007
[3] From April 23, 2007
[4] To December 31, 2006
[5] To January 12, 2007
[6] To May 31, 2007
[7] From June 25, 2007
[8] From February 5, 2007
[9] From May 7, 2007
[10] From July 6, 2006
[11] To July 14, 2006
[12] To March 23, 2007

Carnegie Academy for Science Education

Sarah Bax, *Mentor Teacher*[1]
Guy Brandenburg, *First Light Instructor,*[2] *Mentor Teacher*[1,3]
John Bucchanan, *Mentor Teacher*[1,3]
Derek Butts, *First Light Assistant*[4]
Shaina Byrnes, *Summer Forensics Instructor*[1]
Alexander Cole, *Intern*[1]
Asonja Dorsey, *Mentor Teacher*[1,3]
Nia Doweary, *Intern*[1]
VanNessa Duckett, *Mentor Teacher*[1,3]
Audrey Edmonds, *CASE Coordinator,*[5] *Intern*[1,3]
Julie Edmonds, *Codirector*
Jessica Franklin, *Mentor Teacher*[1]
Ricky Garibay, *First Light Assistant,*[6] *Intern*[1,3]
Joseph Geglia, *Intern*[3]
Tashima Hawkins, *Mentor Teacher*[1,3]
Anne Hemphill, *Mentor Teacher*[1,3]
Gayan Hettipola, *Intern*[1]
Toby Horn, *Codirector*
Loretta Kelly, *Mentor Teacher*[1,3]
Becky Lippy, *Intern*[1]
Robert Lucas, *Intern*[1]
Fran McCrackin, *Mentor Teacher*[1,3]
Thomas Nassif, *Mentor Teacher*[1,3]
Maxine Singer, *Senior Scientific Advisor*
Shahza Somerville, *Summer Biotech Instructor,*[3] *CASE Coordinator*[7]
Annie Thompson, *Mentor Teacher*[1,3]
Latisha Whitley, *Intern*[3]

[1] Summer Institute 2007
[2] From October 21, 2006
[3] Summer Institute 2006
[4] To June 9, 2007
[5] From January 30, 2007, to June 15, 2007
[6] From October 21, 2006
[7] From September 1, 2006, to December 31, 2006

Embryology

Research Staff Members

Alexsky Bortvin
Donald D. Brown, *Director Emeritus*
Chen-Ming Fan
Steven Farber
Joseph G. Gall
Marnie Halpern
Douglas E. Koshland
Allan C. Spradling, *Director*
Yixian Zheng

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David MacPherson
Alex Schreiber
Jim Wilhelm[1]
Judith Yanowitz

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Michael Buszczak, *American Cancer Society Fellowship, Carnegie Fellow*
Liquan Cai, *NIH Grant (Brown)*
Anna Chan, *Howard Hughes Medical Institute Research Associate*[4]
Rachel Cox, *Howard Hughes Medical Institute Research Specialist*
Lucilla Facchin, *Eppley Foundation Grant (Halpern)*[5]
Donald Fox, *Jane Coffin Childs Fellowship*[6]
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Mary Goll, *Damon Runyon Cancer Research Fellowship*
Daniel Gorelick, *Carnegie Fellow*
Vinny Guacci, *Howard Hughes Medical Institute Research Specialist*
Kotaro Hama, *Japan Foundation Fellowship*
Catherine Huang, *American Cancer Society Fellowship*[7]
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Robert Levis, *Special Investigator, NIH Grant (Spradling with Baylor College of Medicine, subcontract)*
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Zhonghua Liu, *Howard Hughes Medical Institute Research Associate*
Safia Malki, *Carnegie Fellow*[9]
Lucy Morris, *Howard Hughes Medical Institute Research Associate*
Sandeep Mukhi, *NIH Grant (Brown)*[10]
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Itay Onn, *Howard Hughes Medical Institute Research Associate*[11]
Joanna Paterson, *Carnegie Fellow*[12]
Kiran Santhakumar, *NIH Grant (Halpern)*

DEPARTMENT OF EMBRYOLOGY

Front row (left to right): Doug Koshland, Yixian Zheng, Joseph Gall, Allan Spradling, Alex Bortvin, Marnie Halpern. Second row (left to right): Jeffrey Han, Zhonghua Liu, Yung-Shu Kuan, Mary Goll, Karina Conkrite, Zehra Nizami, Rong Chen. Third row (left to right): Judith Yanowitz, Lucy Morris, Margaret Hoang, Queenie Vong, Katie Lewis, Rejeanne Juste, Mary Ma, David MacPherson. Fourth row (left to right): Chun Dong, Sandrine Biau, Courtney Akitake, Shelley Paterno, Dianne Wiliams, Ona Martin, Alison Brown, Michelle Macurak, Glenese Johnson. Fifth row (left to right): Kotaro Hama, Dolly Chin, Natalia Wesolowska, Dan Lighthouse, Becky Frederick, Cynthia Wagner, Allison Pinder, Tina Tootle, Ellen Cammon. Sixth row (left to right): Shusheng Wang, Maggie Sundby, Safia Malki, Zheng-an Wu, Itay Onn, Dean Calahan, Jessica Steele, Brian Hollenback, Nicole Gabriel, Amy Kowalski. Seventh row (left to right): Rachel Cox, Anna Allen, Tara Hardiman, Lamia Wabha, Lea Fortuno, Lori Orosco, Eugenia Dikovskaia, Anastasia Krasnoperova. Eighth row (left to right): Jill Heidinger, Carol Davenport, Julio Castaneda, Cheng Xu, Bob Levis, Don Fox, Vinny Guacci, Evan Siple. Ninth row (left to right): Stephen Heitzer, James Walters, Dan Gorelick, Godfried van der Heijden, Todd Nystul, David Martinelli, Wendy McKoy, Zehra Eifert. Tenth row (left to right): Adem Eifert, Lucilla Facchin, Sandeep Mukhi, Mahmud Siddiqi, Christoph Lepper, Andrew Skora, Andrew Eifert, Tom McDonaugh.

Zi-Qing Sun, *Carnegie Fellow*[13]
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Ming-Ying Tsai, *Howard Hughes Medical Institute Research Associate*[14]
Godfried Van der Heijden, *Carnegie Fellow*[15]
Queenie Vong, *Howard Hughes Medical Institute Research Associate*
Cynthia Wagner, *Special Investigator, Carnegie Fellow*
James Walters, *Carnegie Fellow*[16]
Shusheng Wang, *Research Associate, NIH Grant (Zheng)*
Zheng-an Wu, *Special Investigator, NIH Grant (Gall) and Carnegie Fellow*
Cheng Xu, *Carnegie Fellow, NIH Grant (Fan)*
Hong-Guo Yu, *Howard Hughes Medical Institute Research Associate*[17]

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Julio Castaneda, *The Johns Hopkins University*
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Ben Goodman, *The Johns Hopkins University*
Robyn Goodman, *The Johns Hopkins University*
Jill Heidinger, *The Johns Hopkins University*
Margaret Hoang, *The Johns Hopkins University*
Christoph Lepper, *The Johns Hopkins University*
Katherine Lewis, *The Johns Hopkins University*[19]
Daniel Lighthouse, *The Johns Hopkins University*
Peter Lopez, *The Johns Hopkins University*
David Martinelli, *The Johns Hopkins University*
Tim Mulligan, *The Johns Hopkins University*
Zehra Nizami, *The Johns Hopkins University*
Lori Orosco, *The Johns Hopkins University*
Andrew Skora, *The Johns Hopkins University*
Sara Soper (formerly Clatterbuck), *The Johns Hopkins University*
Elçin Ünal, *The Johns Hopkins University*
Lamia Wahba, *The Johns Hopkins University*[20]

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Patricia Cammon, *Howard Hughes Medical Institute Laboratory Helper*
Melinda Campbell, *Technician*

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Rong Chen, *Howard Hughes Medical Institute Research Technician I*[23]
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Karina Conkrite, *Technician*
Carol Davenport, *Howard Hughes Medical Institute Research Technician III*
Eugenia Dikovskaia, *Animal Facility Manager*
Chun Dong, *Research Scientist*[24]
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Andrew Eifert, *Assistant Facility Manager*[26]
Zehra Eifert, *Animal Technician*[27]
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Nicole Gabriel, *Animal Care Technician*
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Tara Hardiman, *Technician*
Javi Hartenstine, *P/T Fish Feeder*[31]
Brian Hollenback, *Animal Technician*[32]
Ella Jackson, *Howard Hughes Medical Institute Laboratory Helper*
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Connie Jewell, *Systems Administrator*
Glenese Johnson, *Laboratory Helper*
Rejeanne Juste, *Technician*
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Allison Pinder, *Howard Hughes Medical Institute Research Technician III*
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Christine Pratt, *Howard Hughes Medical Institute Administrative Assistant II*
Michael Sepanski, *Electron Microscopy Technician*
Shirley Shao, *Volunteer*[35]
Mahmud Siddiqi, *Research Specialist*
Keeyana Singleton, *Howard Hughes Medical Institute Research Technician I*[36]
C. Evan Siple, *Research Technician*[37]
Loretta Steffy, *Accounting Assistant*
Allen Strause, *Machinist*
Yan Tan, *Technician*
Rafael Villagaray, *Computer Technician*
Xin Wang, *P/T Laboratory Help*
Mike Welch, *Technician*[38]
Allisandra Wen, *P/T Fish Feeder*[39]
Dianne Williams, *Howard Hughes Medical Institute Research Technician III*

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James Beck, *Department of Physiology and Neuroscience, New York University School of Medicine*
Hugo Bellen, *Baylor College of Medicine*
Ian Blair, *Department of Chemistry, University of Pennsylvania*
Dana Carroll, *Department of Biochemistry, University of Utah*
Rosalind Coleman, *Department of Nutrition, University of North Carolina*
Michael Dean, *Laboratory of Genomic Diversity, NCI-Frederick*
Maitreya Dunham, *Carl Icahn Laboratory, Princeton University*
Steven Ekker, *Department of Genetics, Cell Biology and Development, University of Minnesota Medical School*
Michael Granato, *Department of Cell and Developmental Biology, University of Pennsylvania School of Medicine*
Matthias Hammerschmidt, *Max-Planck-Institute of Immunobiology, Germany*
Roger Hoskins, *Lawrence Berkeley National Laboratory*
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Peter Kwiterovich, *Department of Pediatrics, The Johns Hopkins University*
Steven Leach, *Department of Surgery, Division of Surgical Oncology, The Johns Hopkins University School of Medicine*
Li Ma, *Laboratory of Molecular Cell Biology and Center of Cell Signaling, Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences*
Michael Parsons, *Departments of Surgery and Oncology, The Johns Hopkins University School of Medicine*
Cecilia Moens, *Fred Hutchinson Cancer Research Center*
Mari Moren, *National Institute of Nutrition and Seafood Research, Norway*
Karen Oogema, *European Molecular Biology Laboratory, Germany*
Erez Raz, *Department of Germ Cell Development, Max Planck Institute for Biophysical Chemistry, Germany*
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Christine Thisse, *Institut de Génétique et de Biologie Moléculaire et Cellulaire, CNRS/INSERM/ULP, France*
Milena Vuica, *Department of Pathology, The Johns Hopkins University School of Medicine*

[1] To October 23, 2006
[2] To August 31, 2006
[3] From March 30, 2007
[4] To February 15, 2007
[5] From March 12, 2007
[6] From November 6, 2006
[7] To January 17, 2007
[8] To July 31, 2006
[9] From September 1, 2006
[10] From July 1, 2006
[11] From April 2, 2007
[12] To September 30, 2006
[13] To January 31, 2007
[14] To January 31, 2007
[15] From April 16, 2007
[16] From January 10, 2007
[17] To August 4, 2006
[18] To March 31, 2007
[19] From June 1, 2007
[20] From June 1, 2007
[21] To October 3, 2006
[22] To July 1, 2006
[23] From January 16, 2007
[24] From February 6, 2007
[25] From June 18, 2007
[26] From December 19, 2006
[27] From June 1, 2007
[28] From December 19, 2006
[29] From May 21, 2007
[30] To August 11, 2006
[31] To January 21, 2007
[32] From February 23, 2007
[33] From December 7, 2006
[34] To September 30, 2006
[35] From September 22, 2006
[36] From August 1, 2006
[37] From July 13, 2006
[38] To September 8, 2006
[39] To May 5, 2007

Geophysical Laboratory

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George D. Cody
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Douglas Rumble III
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Burkhard Militzer
James Scott [3]

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Dimitri A. Sverjensky, *The Johns Hopkins University*
Takamitsu Yamanaka, *Osaka University, Japan* [4]

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Marc Fries, *NASA* [6]
Qi Liang, *CVD Diamond* [7]
Haozhe Liu, *Research Scientist, HPCAT*
Giles Maule, *NASA* [8]
Maddury Somayazulu, *CDAC* [9]
Jian Xu, *Research Scientist, HPCAT* [10]
Chih Shiue Yan, *CDAC, NSF, Carnegie*
Chang-Sheng Zha, *CDAC*

Summer Education Coordinator and Research Scientist
Stephen A. Gramsch, *CDAC Laboratory Manager*

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Arunkumar S. Bommannavar, *Beamline Control Scientist, HPCAT*
Paul Chow, *Beamline Scientist, HPCAT*
Yang Ding, *Beamline Scientist, HPSynC* [11]
Alexander Gavriliuk, *Visiting Scholar, DOE* [12]
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Hui Li, *Visiting Scientist, HPCAT* [15]
Hanns-Peter Liermann, *Beamline Scientist, HPCAT*
Jing Liu, *Visiting Scientist, HPCAT*
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Yue Meng, *Beamline Scientist, HPCAT*
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Guoyin Shen, *Project Manager, HPCAT and HPSynC*
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Stanislav Sinogeikin, *Beamline Scientist, HPCAT*
Lin Wang, *Balzan Fellow, HPCAT* [17]
Wenge Yang, *Beamline Scientist, HPCAT*

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Andrey Bekker, *Carnegie Fellow, NAI*
Razvan Caracas, *Carnegie Fellow and ONR Postdoctoral Associate* [18]
Raja Chellappa, *Postdoctoral Associate, DOE-CDAC, DOE-BES* [19]
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Dionysis I. Foustoukos, *Carnegie Fellow* [23]
Jennifer Jackson, *Carnegie Fellow* [24]
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Alexander Kollias, *Postdoctoral Associate, NSF* [27]
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Heather Watson, *Carnegie Fellow* [39]
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Lin Wang, *Postdoctoral Associate, Balzan Foundation Fund* [41]
Li Zhang, *Postdoctoral Associate, NASA* [42]

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Patrick Griffin, *NAI, Balzan Foundation Fund, Prewitt-Hazen Gift Fund* [45]
Shih-Shian Ho, *NSF* [46]
Yann Le Gac, *Personal Funds*
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Maia Schweizer, *ASTID and NAI, Carnegie* [48]
Sandra Siljeströem, *NASA* [49]
Verena Starke, *NASA Marshall Space Flight Center*
Yu Wang, *NSF* [50]
Yao Wu, *NSF* [51]

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Seth King, *Purdue University*
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Christy Mancuso, *American University*
Ana Maria Molina, *Universidad Pontificia Bolivariana, Columbia*

GEOPHYSICAL LABORATORY
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Zach Newman, *Case Western Reserve University*
Nissa Sandley, *University of Wisconsin, Stevens Point*
Emily Snyder, *American University*
Brian Smith, *Salisbury University*
William Wurzel, *Lafayette College*

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Andrew Kung, *Montgomery Blair High School, Silver Spring, MD*
Torbjorn Lien, *Ullern Videregaende Skole, Oslo, Norway*

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Gary A. Bors, *Building Engineer*[54]
Valance Brenneis, *Laboratory Technician*
Bobbie L. Brown, *Instrument Maker*
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Phillip Davis, *Accounts Payable Specialist*[55]
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[1] To June 30, 2007
[2] To June 15, 2007
[3] To July 31, 2006
[4] From April 3, 2007
[5] To July 1, 2006
[6] From July 1, 2006
[7] From May 1, 2007
[8] From July 1, 2006
[9] From July 1, 2006
[10] Retired April 30, 2007
[11] From May 1, 2007
[12] From March 15 to May 20, 2007
[13] To April 30, 2007
[14] From May 1, 2007
[15] From October 2, 2006, to December 12, 2006
[16] From October 2, 2006, to December 12, 2006
[17] From March 5, 2007
[18] To September 30, 2006
[19] From June 1, 2007
[20] From January 2, 2007
[21] To January 5, 2007
[22] From September 5, 2006
[23] From July 3, 2006
[24] To November 14, 2006
[25] To August 10, 2006
[26] To June 6, 2007
[27] From October 10, 2006, to June 18, 2007
[28] From August 10, 2006
[29] To March 1, 2007
[30] To June 30, 2007
[31] From September 11, 2006
[32] To December 31, 2006
[33] From October 2, 2006
[34] To August 18, 2006
[35] From November 1, 2006
[36] To September 15, 2006
[37] To December 31, 2006
[38] To May 25, 2007
[39] To January 10, 2007
[40] From March 5, 2007
[41] From January 1, 2007
[42] From January 9, 2007
[43] From September 5, 2006
[44] To September 15, 2006
[45] From March 16, 2007
[46] To July 15, 2006
[47] To July 1, 2006
[48] To July 1, 2006
[49] From July 13, 2006, to December 31, 2006
[50] To October 19, 2006
[51] From April 1, 2007
[52] From October 2, 2006, to October 31, 2006
[53] Joint appointment with DTM
[54] Joint appointment with DTM
[55] To April 30, 2007
[56] Joint appointment with DTM
[57] Joint appointment with DTM
[58] To December 31, 2006
[59] From February 1, 2007
[60] Deceased January 10, 2007
[61] Joint appointment with DTM
[62] From May 16, 2007
[63] Joint appointment with DTM
[64] From August 21, 2006, joint appointment with DTM
[65] From February 9, 2007
[66] Joint appointment with DTM
[67] From June 18, 2007
[68] From May 11, 2007
[69] Joint appointment with DTM
[70] Joint appointment with DTM
[71] Joint appointment with DTM
[72] Joint appointment with DTM
[73] Joint appointment with DTM

DEPARTMENT OF GLOBAL ECOLOGY
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Mitsuhiko Tsukimoto, *Laboratory Technician*[16]
Tim Varga, *Laboratory Technician*

[1] To June 1, 2007
[2] From December 1, 2006
[3] To June 30, 2007
[4] From September 1, 2006
[5] To April 1, 2007
[6] From April 16, 2007
[7] To September 8, 2006
[8] From April 16, 2007
[9] From May 1, 2007, to June 30, 2007
[10] To April 6, 2007
[11] From January 2, 2007
[12] To June 1, 2007
[13] To November 15, 2006
[14] To June 30, 2007
[15] From November 16, 2006, to May 3, 2007
[16] From July 10, 2006, to June 8, 2007

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Jorge Rojas, *Janitor*
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From left standing on concrete: Matt Johns, Earl Harris, John Grula, Gregory Walth, Andreas Koch, Alan Uomoto, Sharon Kelly, Mark Seibert, Inese Ivans, George Becker, Tesla Jeltema, George Preston, Patrick McCarthy, Andrew McWilliam, Jennifer Marshall, Barry Madore, Jeffrey Crane, Stephen Shectman, Tyson Hare, Steve Wilson, Juna Kollmeier, John Mulchaey, Scott Rubel, Christoph Birk, Vincent Kowal, François Schweizer, Robert Storts, Alan Bagish. From left on lawn: Silvia Hutchison, Luis Ochoa, Jeanette Stone (on front step), Jane Rigby, Haojing Yan, Edo Berger, Luis Ho, Ian Thompson, Rupali Chandar, Judy Collison, Paul Collison, David Murphy. Front: Jorge Estrada, Greg Ortiz, Wendy Freedman, Ken Clardy, Alan Dressler, Augustus Oemler, Violet Mager, Becky Lynn, Daisuke Kawata, Arnold Phifer, Jerson Castillo. *(Image courtesy Skye Moorhead.)*

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[1] From August 1, 2006
[2] From July 3, 2006
[3] To September 14, 2006
[4] To August 31, 2006
[5] From April 1, 2007
[6] From October 15, 2006
[7] From September 1, 2006
[8] From September 17, 2006
[9] From July 1, 2006
[10] From May 14, 2007
[11] From February 12, 2007
[12] To April 14, 2007
[13] To July 3, 2006
[14] From July 10, 2006
[15] To February 2, 2007
[16] To December 31, 2006
[17] From October 15, 2006; formerly GMT
[18] From February 5, 2007
[19] To August 7, 2006
[20] From November 13, 2006
[21] From August 22, 2006
[22] From May 8, 2007; formerly GMT Site Testing Support
[23] From May 18, 2007
[24] From April 15, 2007
[25] To August 21, 2006

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First row (left to right): Department Visitor, Devaki Bhaya, Payal Joglekar, Sheila Jensen, Kathi Bump, Ying Gu, Nik Pootakham, Cynthia Lee, Guillaume Pilot, Hitomi Takahashi, Nakako Shibagaki, Michele Davison, Choon Kiat Sim, Shauna Somerville, Chris Somerville, Paul Sterbentz (kneeling). Second row (left to right): Unknown, Melisa Lim, Tanya Berardini, Dahlia Wist, Yu Sun, Clarissa Bejar, Khar Wai Lye, Rejane Pratelli, Bhavna Chaudhuri, Jeff Moseley. Third row (left to right): David Gonzalez Ballister, Dominique Loqué, Tae-Wuk Kim, Fariba Fazelli, Meghan Sharp, Kian Hematy, Farzad Haerizadeh, José Estevez, Wolf Frommer, Tom Meyer, Larry Ploetz. Fourth row (left to right): Sylvie LaLonde, Friederike Hoermann, Antoinette Sero, Christian Voigt, Naoia Williams, Natalie Khitrov, Ruiji Wang, Debbie Alexander, Peifen Zhang, Shaolin Chen, Allison Phillips. Fifth row (left to right): Hulya Aksoy, Turkan Eke, William Underwood, Diane Chermak, Kathy Barton, Dave Ehrhardt, Seth DeBolt, Ryan Gutierrez, Stephan Wenkel, Christina Chang, Zhiping Deng, Purna Sudha Bindu Ambaru, Anjelica Vasquez, Raymond Chetty, Chris Wilks. Sixth row (left to right): Arthur Grossman, Susan Cortinas, Maria Gomez Garcia, Liping Ji, Iben Moller-Hansen, Sunita Patil, Matt Evans, Shanker Singh, Dusica Acoska, Suzanne Fleshman, Yi-Shin Su. Seventh row (left to right): Shaun Bailey, Totte Niitlya, Wensheng Qin, Glenn Ford, Myles Barker, Florence Mus, Andrew Carroll, Ozgur Ozturk, Maria Sardi, Kate Dreher, Phillipe Lamesch, Donghui Li, David Swarbreck, Ismael Villa, Kun He, Wenqiang Tang, Zhiyong Wang.

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[1] From August 1, 2006, to June 15, 2007
[2] From January 1, 2007
[3] From June 1, 2007
[4] From July 1, 2006, to September 30, 2006
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[78] To February 14, 2007
[79] To September 6, 2006
[80] From November 30, 2006
[81] To November 7, 2006
[82] To April 23, 2007
[83] From February 5, 2007
[84] From July 10, 2006
[85] From April 24, 2007
[86] From April 1, 2007
[87] From June 11, 2007

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[1] To December 31, 2006
[2] To December 31, 2006
[3] From October 11, 2006
[4] From January 3, 2007
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Here updated through Sept. 30, 2007. Reprints of the numbered publications are available, except where noted, at no charge from the Librarian, Geophysical Laboratory, 5251 Broad Branch Road, NW, Washington, DC 20015-1305 (e-mail: library@dtm.ciw.edu). Please give reprint number(s) when ordering. The list is regularly updated on the laboratory's Web site (http://www.gl.ciw.edu/).

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