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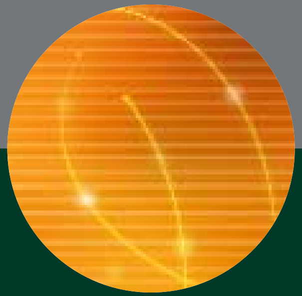

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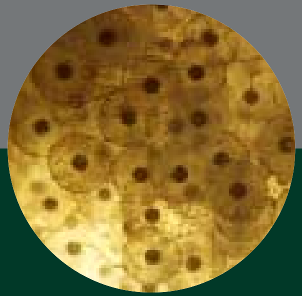



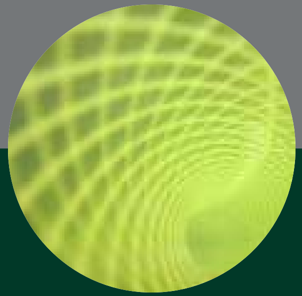

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2005-2006 YEAR BOOK

THE PRESIDENT'S REPORT

July 1, 2005 - June 30, 2006

CARNEGIE INSTITUTION
OF WASHINGTON

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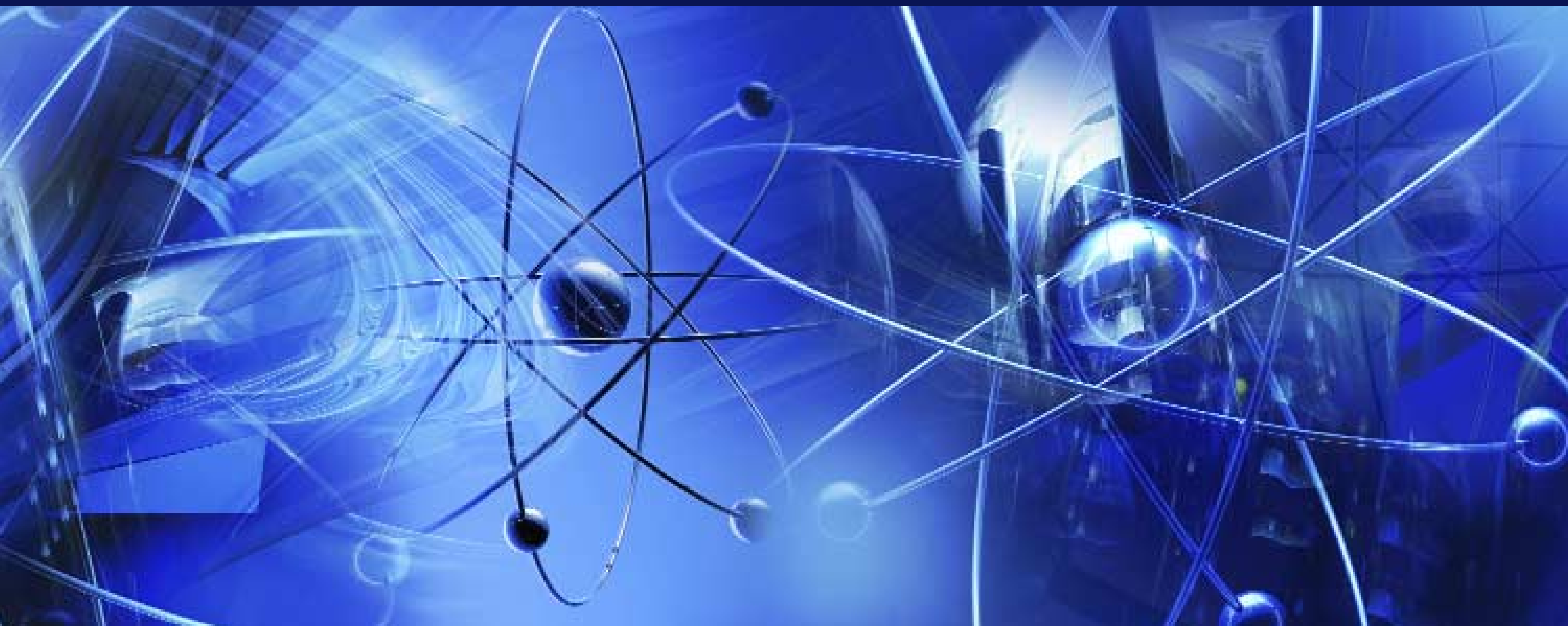
ABOUT CARNEGIE

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

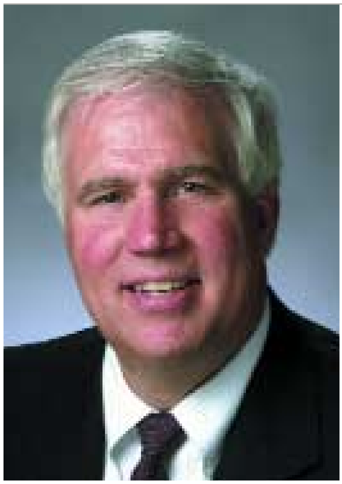
The Carnegie Institution of Washington was incorporated with these words in 1902 by its founder, Andrew Carnegie. Since then, the institution has remained true to its mission. At six research departments across the country, the scientific staff and a constantly changing roster of students, postdoctoral fellows, and visiting investigators tackle fundamental questions on the frontiers of biology, earth sciences, and astronomy.

CARNEGIE INSTITUTION



CONTENTS

THE PRESIDENT'S COMMENTARY



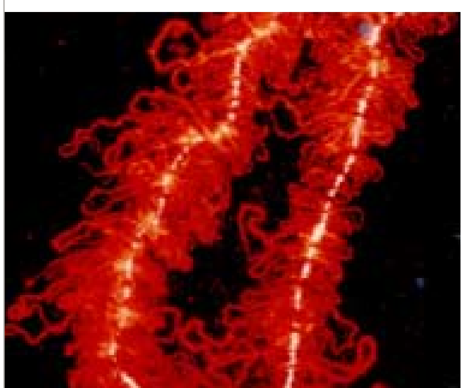
Carnegie president
Richard A. Meserve
(Image courtesy Jim Johnson.)

Two thousand six was a banner year for Carnegie. Three of our scientists were awarded major prizes and our scientific staff published prolifically in many prestigious journals, as is shown elsewhere in this Year Book. The institution also raised its profile in the popular media, as several of our scientists were regularly sought for comment on such matters as the planetary status of Pluto or the looming threat of global warming. Although this small institution has always been disproportionately influential, this past year will likely be remembered as a landmark for acknowledgment of our accomplishments.

Our Exceptional Scientists

Andrew Fire, now at Stanford University, spent 17 years in Carnegie's Department of Embryology. This year he shared the Nobel Prize in Physiology or Medicine with his colleague Craig Mello of the University of Massachusetts for work that he performed at Carnegie on RNA interference (RNAi). Although Andy received some modest NIH grants during his time at Carnegie, most of his Nobel-winning work was funded by Carnegie's endowment. His achievements are a ringing endorsement of the Carnegie philosophy of finding and supporting exceptional individuals.

Arabidopsis thaliana is the most widely used model plant for genetic studies. Plant Biology director Christopher Somerville was a pioneering advocate for its use.



Embryology's Joe Gall uses the extremely large lampbrush chromosomes from egg cells of the frog *Xenopus* in much of his work. A fluorescent antibody produces the glow in this lampbrush.
(Image courtesy Joseph Gall.)

One type of RNA is the messenger that transfers genetic information stored in DNA to the protein factories that implement the genetic instructions. Andy and Craig discovered a means to regulate gene expression by inactivating the capacity of this RNA to transmit genetic information. The technique has great significance because it enables the study of the function of a gene by adding a specific nucleic acid that turns off gene expression. This means that scientists can learn about gene function without first creating a mutant with the gene removed or inactivated. The new approach also expands functional genetic studies beyond a few model organisms for which methods of removing or disabling genes were well developed.

It also turns out that RNAi is a primitive control system with evolutionary significance. It may play a role in development by directing genes to turn on or off at various stages. And although RNAi was discovered just a few years ago, medical therapies employing it are already in clinical trials. In short, this fundamental advance promises to have paradigm-shifting impact.

Christopher Somerville, the director of Carnegie's Department of Plant Biology, shared the Balzan Prize in plant molecular genetics with Elliot Meyerowitz of Caltech. Chris was an early advocate of the use of *Arabidopsis*, a relative of the mustard plant, as a model organism for the study of molecular genetics. He also played an important role in the sequencing of the plant's genome. The department now houses The Arabidopsis Information Resource (TAIR), an open-source repository of genetic information about this plant. With about 12 million page hits per year, TAIR is perhaps the most extensively used biological database in the world.

Arabidopsis has become the genetic workhorse of plant biology, taking on the same role that the fruit fly and the mouse play for animal biology. Chris has helped to shape the very direction of his discipline as a result of his vision regarding this plant. He has also made fundamental contributions to the understanding of carbon dioxide fixation by photosynthesis, of lipid metabolism in plants, and, more recently, of the synthesis of cell walls using lignin and cellulose. The latter is critically important because of the role that biofuels are likely to play in humankind's response to the threat of climate change.

Joseph Gall, a staff member in Carnegie's Department of Embryology, was awarded the 2006 Albert Lasker Award for Special Achievement in Medical Science in recognition of his amazingly productive 57-year career. The Lasker Award, sometimes called the American Nobel, acknowledges Joe's role as "a founder of modern cell biology and the field of chromosome structure and function."[1] Through his study of exceptionally large chromosomes in amphibian eggs, termed lampbrush

Department of Terrestrial Magnetism (DTM) staff take a break from installing a Sacks-Evertson borehole strainmeter on the Greek island of Trizonia in 2002. Strainmeters consist of a metal tube filled with liquid that, when buried in the ground, detects minute changes in the strain of surrounding rocks. They have been installed in seismically and volcanically active regions around the world. Shown from left are Alan Linde, Pascal Bernard (l'Institut de Physique du Globe de Paris), Brian Schleigh, Nelson McWhorter, a local driller, and Selwyn Sacks.

chromosomes, Joe was able to show that each chromosome is composed of a single DNA double helix and that the chromosome loops are made of genes that are copied into RNAs that are stored for use in fabricating a new individual—a core component of the molecular machinery of life.

Joe also developed the technique of in situ hybridization. This technique allows scientists to pinpoint the locations of specific RNA or DNA sequences in the cell and determine whether a gene has been turned on in a developing embryo. His methodology became one of the most widely used techniques in cell biology and remains a standard method for gene mapping.

With over five decades at the bench, Joe is still exploring the mysteries of biology. He now is studying a structure in the nucleus called the Cajal body, which he believes may be critical for processing messenger RNAs. It has been observed that "Gall's legacy has already permeated cell biology textbooks and will reach far into the future through the biological problems and people he has touched."[1]

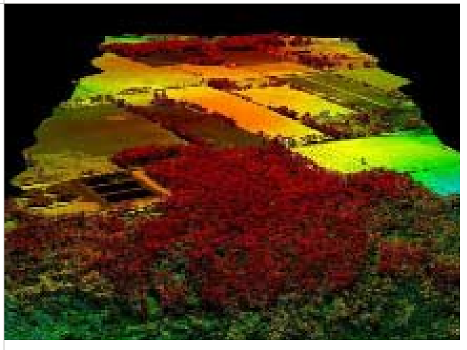
Indispensable Instruments

People are clearly the most important part of the equation for successful scientific research, but advanced equipment is also essential. As a result, Carnegie seeks not only to provide a home for exceptional individuals but also to nurture their efforts to develop instruments with new and exciting capabilities. A few examples follow.

Strainmeters. Selwyn Sacks of our Department of Terrestrial Magnetism (DTM) developed a very sensitive borehole strainmeter (in collaboration with Dale Evertson of the University of Texas and DTM staff instrument maker Mike Seemann) in order to overcome the limited sensitivity of previous seismic instruments. These strainmeters are filled with hydraulic fluid and, by measuring flow of the fluid from one chamber to another, can detect otherwise imperceptible movements in the host rock. Such strainmeters are now used by geophysicists around the globe and have demonstrated that earthquake faults can move slowly as well as quickly and destructively, among other unexpected results.

Strainmeters are deployed in earthquake-prone areas around the globe, such as along the San Andreas Fault in California. In fact, a major effort is now under way to deploy thousands of these strainmeters across the United States. Funded by the National Science Foundation and supported by the U.S. Geological Survey, this network will foster a deep understanding of how the Earth redistributes geologic stresses.

DTM's Alan Linde uses these same devices to monitor the pressure and movement of fluids in magma chambers, thereby providing insights into the "plumbing" of volcanoes. Sacks and Linde have recently used strainmeters to show that environmental changes, such as the drop in atmospheric pressure from a typhoon, can bring about changes in geologic stress. In short, these versatile instruments are now a standard for seismic studies into various Earth processes.



(TOP) Global Ecology's Greg Asner and team designed and built the Carnegie Airborne Observatory (CAO), which includes instruments for high-fidelity imaging spectroscopy (HFIS) to measure biochemical indicators and scanning-waveform light detection and ranging (LiDAR) to map the physical structure of vegetation. This is a LiDAR image of forests and pasturelands on the Big Island of Hawaii. *(Image courtesy Greg Asner.)*

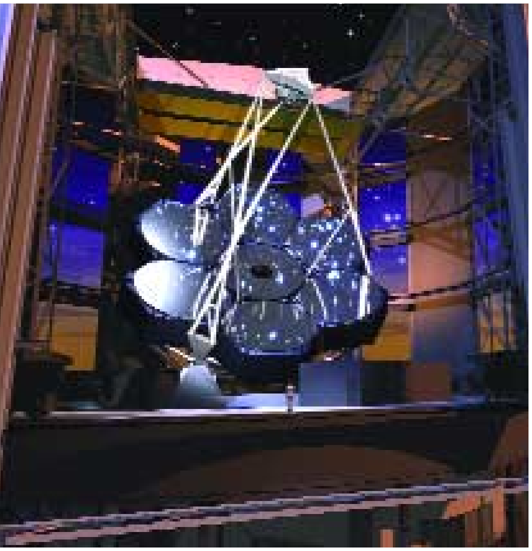
(BOTTOM) The Geophysical Laboratory's Jake Maule (left) and colleague Norm Wainwright test the Lab-on-a-Chip in zero gravity aboard NASA's C-9 parabolic aircraft. *(Image courtesy Reduced Gravity Office, NASA Johnson Space Center.)*

Ecological Measurements. Greg Asner and his team at Carnegie's Department of Global Ecology designed and built the Carnegie Airborne Observatory (CAO) with financial support from Carnegie trustee Will Hearst and the W. M. Keck Foundation. This instrument, which can be flown on a variety of aircraft, employs high-fidelity imaging spectroscopy (HFIS) to measure biochemical indicators, and scanning-waveform light detection and ranging (LiDAR) to map the physical structure of vegetation. Together, the instruments provide quantitative insights into ecosystem physiology, biogeochemistry, and hydrology on a regional basis.

The CAO promises to open a new, high-resolution window on the changing composition of our land and ocean environments. Greg has already employed other remote sensing tools to monitor desertification in the American Southwest, the intrusion of invasive species in Hawaii, and the wide-scale prevalence of selective logging in the Amazon. The CAO will no doubt prove to be an essential tool for monitoring ecological threats.

Detection of Life. Humankind has always wondered if there is life beyond Earth. Andrew Steele and his colleagues at the Geophysical Laboratory and DTM are developing instruments to look for current or past life on Mars, one of the most probable additional havens for life in our solar system. Their small, rugged, "Lab-on-a-Chip" devices are designed to detect and analyze the proteins, lipids, and sugars indicative of living things.

Following exhaustive laboratory testing, Steele's instruments are field-tested in taxing environments, such as the Arctic (as part of the Artic Mars Analogue Svalbard Expedition), the Arizona desert, and in zero-G simulations. One instrument flew to the International Space Station aboard the space shuttle *Discovery* in December 2006, and three of the group's instruments are slated to fly on NASA's *Mars Science Lander* in 2009.



The Giant Magellan Telescope is slated for completion around 2016. It will consist of seven 8.4-meter primary mirrors arranged in a hexagonal pattern. The telescope's primary mirror will have a diameter of 80 feet (24.5 meters) with more than 4.5 times the collecting area of any current optical telescope and 10 times the resolution of the Hubble Space Telescope.

(Image courtesy Todd Mason and The Carnegie Observatories.)

Telescopes. Some of the most astonishing scientific results of the first half of the 20th century were the result of studies conducted with the progressively larger telescopes sponsored by Andrew Carnegie and others. Carnegie astronomer Edwin Hubble, for example, showed that the Milky Way was just one of millions of galaxies. He then demonstrated that the universe was expanding—an observation that helped to corroborate the Big Bang theory. The key to these discoveries was the availability of telescopes of increasing size to collect more light, thereby enabling astronomers to peer ever deeper into space.

Today, astronomers at the Carnegie Observatories, along with some intrepid colleagues at a group of sister institutions, are proceeding with plans to build a telescope with the resolving power of a 24.5-meter (80-foot) primary mirror—far larger than any other telescope ever built. It will be constructed of seven mirror segments, each 8.4 meters in diameter. The fabrication and testing of one of the off-axis mirrors, a major technical challenge, is now under way. The telescope will provide an enormous leap in capability—it will allow images up to 10 times sharper than those produced by the Hubble Space Telescope—and is likely to reveal cosmological surprises that are beyond imagining.

It is challenging to limit myself to only these few examples, as every corner of the institution reveals exciting research. The accomplishments of our staff scientists, postdoctoral researchers, and graduate students serve as proof, if proof were needed, that Andrew Carnegie's original vision of finding exceptional scientists and providing them with the means to express their brilliance is a timeless recipe for success. I look forward to sharing more stories of extraordinary achievement with you next year.

Richard A. Meserve

[1]Evelyn Strauss, 2006 Albert Lasker Award for Special Achievement in Medical Science, at http://www.laskerfoundation.org/awards/library/2006special.shtml.

FRIENDS, HONORS & TRANSITIONS

CARNEGIE FRIENDS

Recognizing Our Benefactors

In 1902, Andrew Carnegie pledged to support innovative researchers of exceptional ability in an environment free from the constraints found in most other research organizations. To this end, he created and endowed the Carnegie Institution. Carnegie scientists are financed largely by endowment income and other revenues; the balance comes from generous individuals and organizations who share the Carnegie vision.

Philanthropic support for the Carnegie Institution allows these scientists to pursue high-risk, high-reward research, putting them at the forefront of their fields. Our primary benefactors play a key role in strengthening Carnegie's ability to fulfill its critical mission. Starting this year, individuals who donate $10,000 annually and those who have made significant cumulative donations will be recognized as members of the **Carnegie Philanthropic Societies.** These societies recognize individuals who have given at different levels. **The Barbara McClintock Society** recognizes individuals who contribute $10,000 or more in a fiscal year. **The Carnegie Founders, Edwin Hubble,** and **Vannevar Bush Societies** honor individuals who have made lifetime contributions of $10 million, $1 million, and $100,000 respectively. **Second Century Society** members have contributed to Carnegie through planned giving. This listing reflects contributions received between July 1, 2005, and June 30, 2006.

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 or Medicine for her work on patterns of genetic inheritance. She was also 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.

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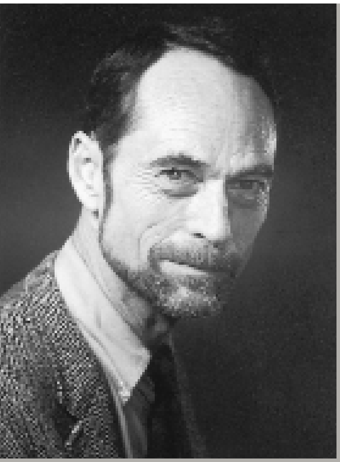


David Greenewalt

Giving to Carnegie: A Family Tradition

The Greenewalt family has a special place in Carnegie history. For over a half century it has made giving to the institution a family affair. Its legacy of support began with Crawford, an engineer and former president and chairman of E. I. du Pont de Nemours and Company. He joined the Carnegie board of trustees in 1952 and was an active member for 32 years. He became particularly interested in Carnegie astronomy. When the institution began to plan for an observatory in the Southern Hemisphere, he and his wife, Margaretta, contributed substantially to the construction of the 2.5-meter Irénée du Pont telescope at Las Campanas, Chile. The telescope was named after Mrs. Greenewalt's father. Later, the Carnegie board honored Crawford with the establishment of the Crawford H. Greenewalt Chair at the Observatories, which is currently held by Director Wendy Freedman.

In 1992 Crawford's son David, a geophysicist and oceanographer at the Naval Research Laboratory in Washington, D.C., followed in his father's footsteps and became a member of the Carnegie board. In 1999 he was elected board secretary. Like his father, he was exceptionally active in Carnegie affairs with his wife, Charlotte. David took great pleasure in chatting directly with researchers and gave generously to Carnegie science until his death in 2003.

In recognition of David Greenewalt's strong ties to the institution, his love for science, and his enthusiasm for the Earth sciences in particular, the board of trustees named the refurbished experiment building at the Broad Branch Road Campus in Washington, D.C., after him in the fall of 2006.

The Greenewalt family is foremost in its support of Carnegie science, donating a total of $8.5 million over the decades. The institution is sincerely grateful for its singular legacy of giving. Countless scientists have been able to fulfill their research dreams through the Greenewalts' enduring generosity.

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
Crawford H. Greenewalt*
David Greenewalt*
Margaretta Greenewalt*
William R. Hearst III
Richard E. Heckert
Kazuo Inamori
Burton J. McMurtry
Jaylee M. Mead
Deborah Rose, Ph.D.
Thomas N. Urban
Sidney J. Weinberg, Jr.

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)
Philip H. Abelson*
Bruce Alberts
Daniel N. Belin
A. James Clark
Tom Cori
John Diebold*
Jean W. Douglas
James Ebert*
Bruce W. Ferguson
Stephen P. Fodor
William K. Gayden
Robert and Margaret Hazen
Henrietta W. Hollaender*
Antonia A. Johnson
Gerald D. Laubach
John D. Macomber
Steven L. McKnight
J. Irwin Miller*
Alvin E. Nashman
Evelyn Stefansson Nef
Alexander Pogo*
Cary Queen
Elizabeth M. Ramsey*
Vera Rubin
William J. Rutter
Maxine F. Singer
Frank Stanton*
Christopher T. 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.

Philip H. Abelson*
Gordon Allen
Bradley F. Bennett
Francis R. Boyd*
Eleanora Dalton
Hugh H. Darby
Julie D. Forbush*
M. Charles Gilbert
Kirsten H. Gildersleeve
Caryl P. Haskins*
Robert and Margaret Hazen
Paul N. Kokulis
Gilbert V. Levin
Evelyn Stefansson Nef
Maxine F. Singer
Frank Stanton*
Hatim A. Tyabji

*deceased | *Members were qualified with gift records we believe to be accurate. If there are any questions, please call Mira Thompson at 202-939-1122.*

HONORS & TRANSITIONS

★ *Sandra Faber*

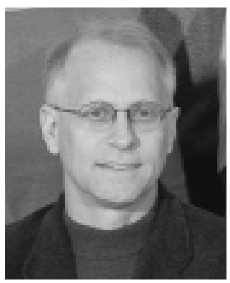
★ *Charles H. Townes*

★ *Andrew Fire*

(Image courtesy Stanford News Service.)

★ *Joseph Gall*

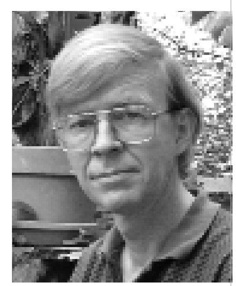
★ *Allan Spradling*



★ *Russell Hemley*

★ *Ho-kwang (Dave) Mao*

★ *Wesley Huntress, Jr.*



★ *Bjørn Mysen*

HONORS

Trustee and astronomer **Sandra Faber** was awarded the Centennial Medal of the Harvard University Graduate School of Arts and Sciences in June in recognition of her contributions to society stemming from graduate education at the university. In July she received the Medal of the Institute for Astrophysics of Paris for her work on dark matter, the discovery of black holes at galactic centers, and the existence of large-scale motions of the Hubble flow.

Trustee emeritus **Charles H. Townes** received the 2006 Vannevar Bush Award from the National Science Board for his lifelong contributions to research and scientific advocacy.

Embryology

Former Embryology staff member **Andrew Fire** was awarded the 2006 Nobel Prize for Physiology or Medicine, with colleague Craig Mello, for their work on RNA interference. Fire conducted the research while at Carnegie.

Joseph Gall received the 2006 Albert Lasker Award for Special Achievement in Medical Science for his “distinguished 57-year career” in cell biology.

Department director **Allan Spradling** was elected president of the Genetics Society of America for 2006.

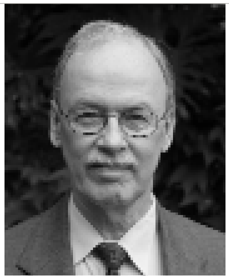
Geophysical Laboratory

The International Balzan Foundation awarded staff scientists **Russell Hemley** and **Ho-kwang (Dave) Mao** the 2005 Balzan Prize for Mineral Physics in November 2005 for their work in high-pressure physics.

Department director **Wesley Huntress, Jr.**, was appointed U.S. representative to a United Nations committee organizing a celebration for the 50th anniversary of the inauguration of the space age with the launch of Sputnik.

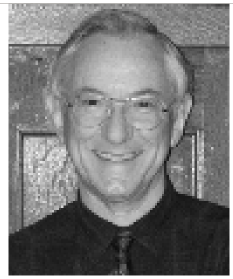
Staff member **Bjørn Mysen** was corecipient of the George W. Morey Award from the American Ceramic Society in May for the book *Silicate Glasses and Melts: Properties and Structure.*

★ *Wendy Freedman*



★ *Christopher Somerville*

★ *Kathy Barton*



★ *Sean Solomon*

★ *Larry Nittler*

★ *Michael Brin*

★ *Ken Caldeira*

★ *Alexander Goncharov*

★ *David MacPherson*

★ *Jeffrey Han*

Observatories

Department director **Wendy Freedman** received the 2005 Klopsteg Memorial Award from the American Association of Physics Teachers.

Plant Biology

The International Balzan Foundation awarded Plant Biology director **Christopher Somerville,** with colleague Elliot Meyerowitz, the 2006 Balzan Prize for their work in plant molecular genetics.

Staff member **Kathy Barton** was elected to the Genetics Society of America's board of directors.

Terrestrial Magnetism

Department director **Sean Solomon** received a Distinguished Alumni Award from Caltech in May 2006.

Staff member **Larry Nittler** was awarded the Antarctic Service Medal in December 2005 for his work with the 2000-2001 Antarctic Search for Meteorites team.

TRANSITIONS

Michael Brin was elected to the board of trustees in May 2006.

On July 1, 2005, **Ken Caldeira** joined the Department of Global Ecology and **Alexander Goncharov** joined the Geophysical Laboratory, both as staff scientists.

David MacPherson and **Jeffrey Han** were appointed staff associates at the Department of Embryology on September 1, 2005, and January 1, 2006, respectively.

RESEARCH HIGHLIGHTS

EMBRYOLOGY

Deciphering the Complexity of Cellular, Developmental, and Genetic Biology

Seeking a Framework for Cell Division

Cell division, or mitosis, might look simple from our end of the microscope, but it is actually a painstaking process. As in a carefully managed divorce settlement, each resulting cell receives half of everything, including the parent cell's DNA.

Yixian Zheng and her colleagues at Embryology have found that a protein with an established role in interphase—the period that separates phases of mitosis—is also vital for cell division. The discovery fills in some important missing facts about the process and could have a significant impact on studies of tissue and organ development, stem cell biology, and cancer.

Scientists have long known about microtubules—the protein "ropes" that tug at chromosomes during cell division. But they are still looking for a structure called the spindle matrix, which acts as a framework to keep microtubules and DNA (in the form of chromosomes) organized during division. So far, most attempts to identify the matrix have focused on proteins that only function in mitosis.

Logical though this strategy might be, it excludes any protein that is active at all times. Zheng and colleagues reasoned that double-duty proteins might form the spindle matrix in dividing cells, and then convert to another function when the cells are in interphase. One protein, called lamin B, is known to help organize the cell's nucleus. When a cell divides, the nucleus temporarily disintegrates, and so researchers had thought that lamin B was simply inactive during mitosis.

Zheng's team tagged lamin B molecules in frog's eggs with fluorescent antibodies and found that the protein collects near the chromosome-splitting microtubules—too close to be a coincidence. Then they interfered with the lamin B gene in cultured human cells and observed severe disruption of cell division. Several more experiments strengthened the case for lamin B's role in the long-sought spindle matrix.

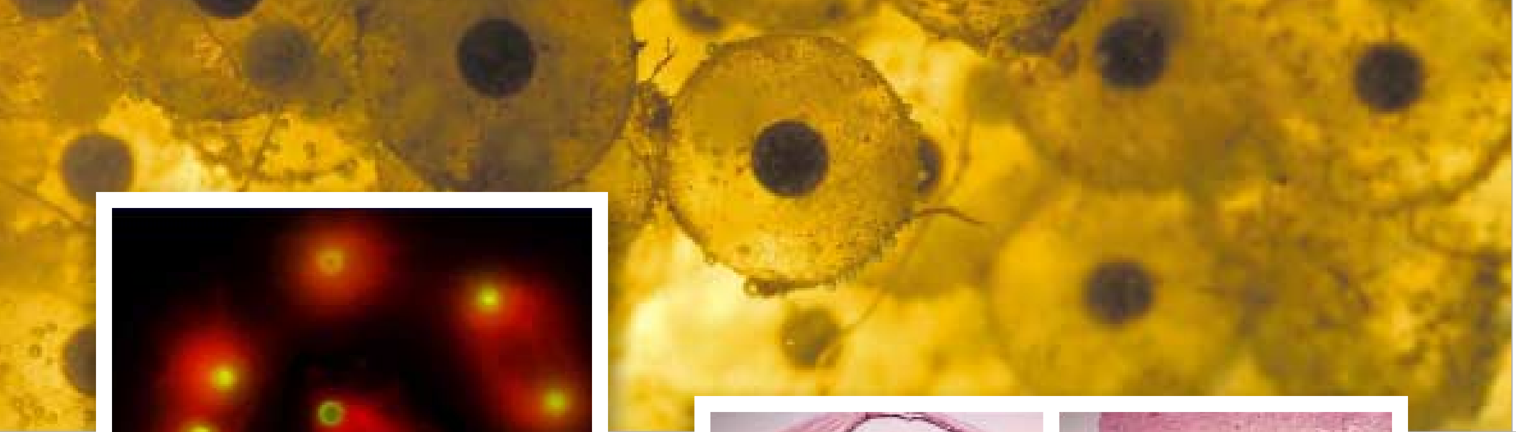
Mutations in lamin proteins have already been implicated in a number of conditions such as premature aging, and more research is likely to strengthen such connections. Nonetheless, the discovery of lamin B's role in the spindle matrix is a leap forward in the study of cell division, with clear implications for human biology and health.

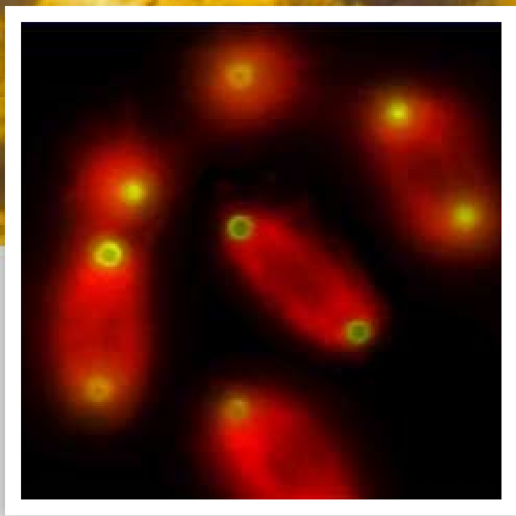
Mice Aid the Study of Human Eye Cancer

Every year in the United States, a malignant cancer called retinoblastoma causes retinal tumors in about 300 children under the age of three. The condition is rare; leukemia, by contrast, affects 10 times as many children. Yet retinoblastoma is among the most heritable human cancers known, and has been traced to a defect in a critical gene called *Rb*.

Laboratory mice with this defect do not develop tumors as humans do, which initially made it difficult to study the condition. Embryology staff associate David MacPherson and colleagues have engineered the first breedable mice that develop such tumors. They now use these mice to study retinoblastoma.

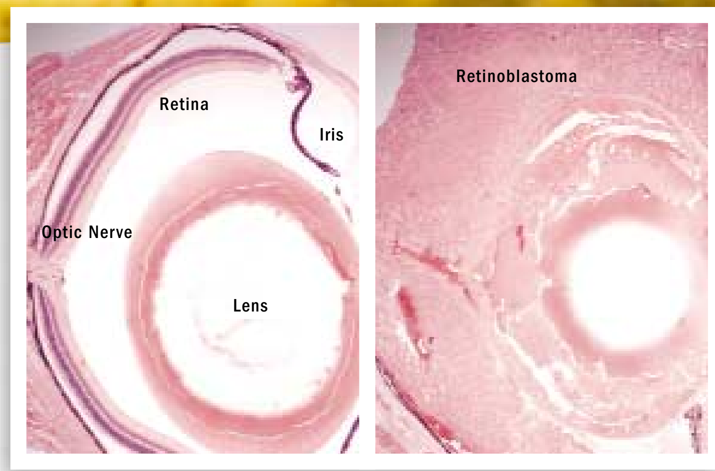
The *Rb* gene was the first to be identified as a tumor suppressor—a gene that contributes to cancer when inactivated. As with all genes, tumor suppressor genes have two copies; both copies must be damaged, or





This image contains several spindles—the structures that carefully divide a cell's genetic material. To better understand their function, Yixian Zheng and colleagues stimulate spindle formation using protein-linked magnetic beads (green/yellow dots). The red fibers are microtubules—protein "ropes" that tug at chromosomes during cell division.

(Image courtesy Yixian Zheng,)



A normal mouse eye (left) is shown in side view next to one with the malignant eye cancer called retinoblastoma. Cancer cells make up the large amount of extra material between the lens and the retina.

(Image courtesy David MacPherson.)

mutated, for cancer to result. In human retinoblastoma, the pattern of mutation—either inherited or spontaneous—determines whether multiple tumors will form in both eyes or a single tumor will form in one eye.

There are many unanswered questions about retinoblastoma. MacPherson's highest priority is to identify the specific retinal cell type from which these tumors arise and to understand how these cells become altered in the process. To answer such questions, researchers need a model organism. Since *Rb* mutations alone do not lead to retinoblastomas in mice, researchers began by looking for other genes that are similar to *Rb*. For his graduate work, MacPherson focused on one such gene, called *p130*. This "retinoblastoma-like" gene seems to compensate for a defective *Rb* gene and protects the mouse from tumor growth. However, when *p130* is mutated in combination with *Rb*, tumors form.

The MacPherson lab is using the retinoblastoma-prone mice to study when and where tumors originate and how they advance. Using technology that allows a comparison of genes in a cancer cell to those of normal cells, the researchers found that some tumors have extra copies of certain DNA regions. Instead of having only two copies of certain genes, as normal cells have, some retinoblastoma cells have multiple or "amplified" genes.

MacPherson's team traced one of the amplified regions to a specific gene called N-*myc*, which is known to cause cancer. However, other amplified regions do not contain known cancer genes. MacPherson believes the mouse data will help in the identification of other cancer-causing genes that influence retinoblastoma.

The mice should help the study of *Rb*'s role in normal retinal development as well as tumor formation. Such work could aid in the design of therapies to save the sight of children with retinoblastoma, and could possibly help to combat many other malignancies in which *Rb* is inactivated. •

GEOPHYSICAL LABORATORY

Probing Planet Interiors, Origins, and Extreme States of Matter

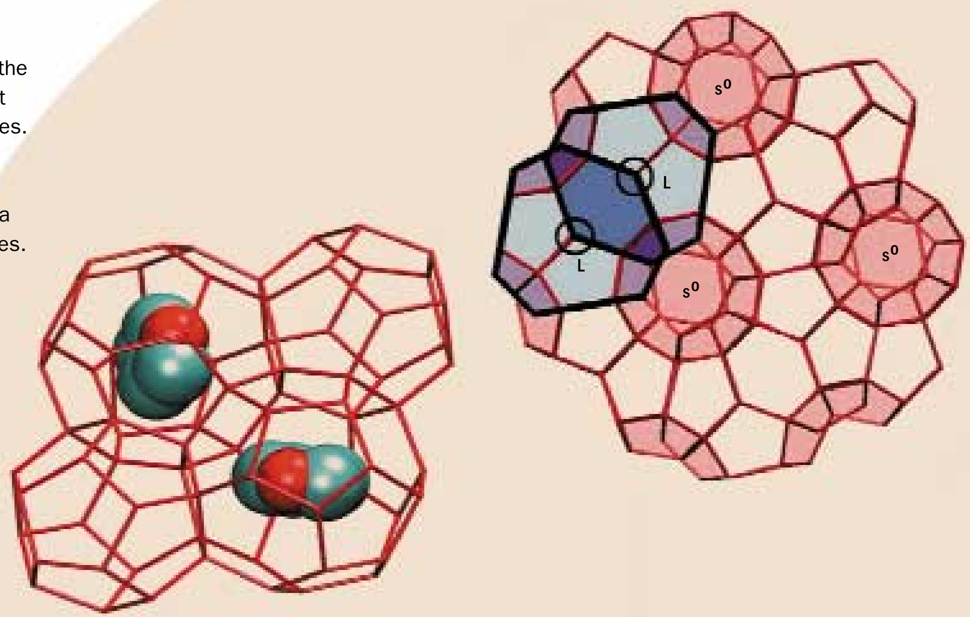
Beyond Petroleum: Into the Hydrogen Era

With sticker shock at the gas pump and an unsettled Middle East, there is intensified interest in finding alternative ways to power our cars. Using theory and experimentation, researchers at the Geophysical Laboratory (GL) have made significant progress in harnessing hydrogen gas (H_2), an environmentally friendly alternative to polluting fossil fuels. Although hydrogen is the most abundant gas in the universe, it has proven difficult to store practically, especially in tanks small enough for cars.

GL researchers Viktor Struzhkin, Burkhard Militzer, Tim Jenkins, Ho-kwang (Dave) Mao, Russell Hemley, Wendy Mao (now at Los Alamos National Laboratory), and collaborators are refining the use of molecule-sized, multicompartment cages of water ice, called clathrate hydrates, to encase and store hydrogen gas at practical temperatures and pressures.

Building on the 2002 experiments by Dave Mao and Wendy Mao, which trapped hydrogen gas inside the water ice structures under high pressure and low temperature, researchers at GL have been testing different clathrate structures to identify bigger cages with more capacity as well as to find additional components that will stabilize the structures under normal temperatures and pressures.

Clathrate compounds are typically stable under high pressure or at low temperatures (-189°F, or 150 K). They



Tetrahydrofurane (THF) (left) occupies the larger cages, leaving the hydrogen (not shown) free to occupy the smaller cages. These type II clathrate structures—molecule-sized cages (right)—consist of 16 small and eight large cages in a cubic unit cell with 136 water molecules. *(Image courtesy B. Militzer and T. Jenkins.)*

come in two main structures: type I and type II—each of which has two types of cavities capable of storing different "guest" molecules. The scientists found that if they added tetrahydrofurane (THF), a chemical used in industry, to type II clathrates, the structure could trap more hydrogen molecules under lower pressure (about 3,000 times the atmospheric pressure at sea level, or 300 MPa) and at a temperature closer to ambient (9.6°F, or 250 K). The use of the chemical also made the structures more stable. Type II clathrates have a set of small and larger cavities. The THF occupied the larger cavities, providing structural integrity for the hydrogen, which resided in the smaller cavities.

Although a primary benefit of this research is to help solve the energy dilemmas facing the nation, the work has a bonus. It points to the possibility that hydrogen might exist in icy bodies in our solar system thought incapable of retaining it.

Burkhard Militzer (left) and Viktor Struzhkin at the Geophysical Laboratory

(Image courtesy Viktor Struzhkin.)

Making the Materials of Tomorrow Today

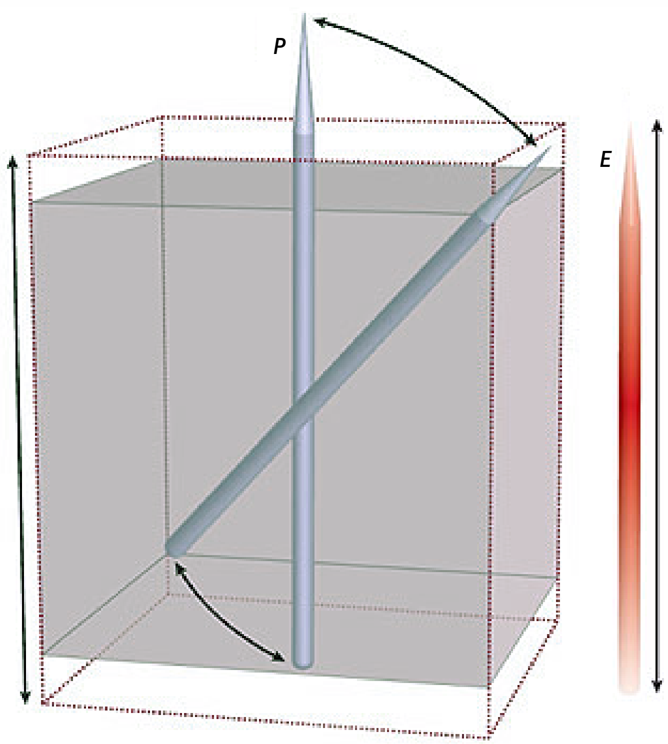
Have you ever wondered how car buzzers or medical ultrasound works? They, and other gadgets, depend on materials known as piezoelectrics, crystals that translate electrical energy into mechanical energy and vice versa—a characteristic known as the piezoelectric effect. The best piezoelectrics tend to be ferroelectric, which means that they have an electric polarization (dipole moment per volume) that is switchable with an applied electric field. Theoretician Ronald Cohen and colleagues have developed a fundamental understanding of these complex materials. They have developed a theory for the origin of ferroelectricity that has enabled detailed predictions of electromechanical properties as well as explanations of the behavior of a new class of these substances that has 10 times the power of currently used materials. Their work not only reveals how these important substances work; it is also used to screen new potential ferroelectrics and is helping to revolutionize devices in fields as diverse as knifeless surgery, sonar, and homeland security.

Using sophisticated computer simulations, Ronald Cohen, Huaxiang Fu, and their colleagues proposed that the secret of these supersubstances lies in the way their polarization behaves in the presence of an electrical field. Cohen and his team model the behavior of matter using first-principles calculations. They begin with the most fundamental properties of a system, such as the nuclear charges of the atoms, and then calculate what happens to matter under different physical conditions. The group has modeled countless ferroelectrics and has even created

Geophysical Laboratory, CONTINUED

In a standard application of piezoelectrics—crystals that translate electrical energy into mechanical energy and vice versa—an electric field is applied in the same direction as the polarization: the field and polarization are collinear. Carnegie theoreticians Ron Cohen and Huaxiang Fu modeled the outcome of an electrical field that is applied obliquely (the electric field is the diagonal axis in the cube) to the direction of the polarization (vertical axis *P* in the cube). They found that the polarization easily rotates from the diagonal position to align with the field (vertical direction) in a phenomenon they called polarization rotation, giving a much larger piezoelectric effect. The large shape and strain changes from the movement are responsible for the giant piezoelectric effect in new strong coupling materials called relaxor piezoelectrics as well as in PZT, the most commonly used piezoelectric.

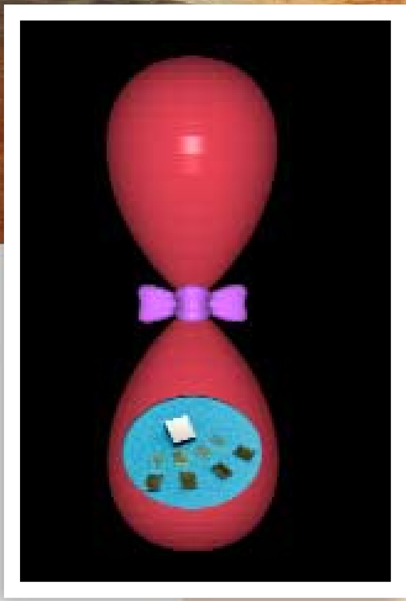
(Image courtesy Nature 441, 941, © Nature *Publishing, June 22, 2006.)*



new ones in an effort to understand the mysteries of the piezoelectric effect and to design new, useful materials. To devise new candidate materials and help interpret results from experiments, Cohen's team works closely with experimentalists at the Geophysical Lab and elsewhere.

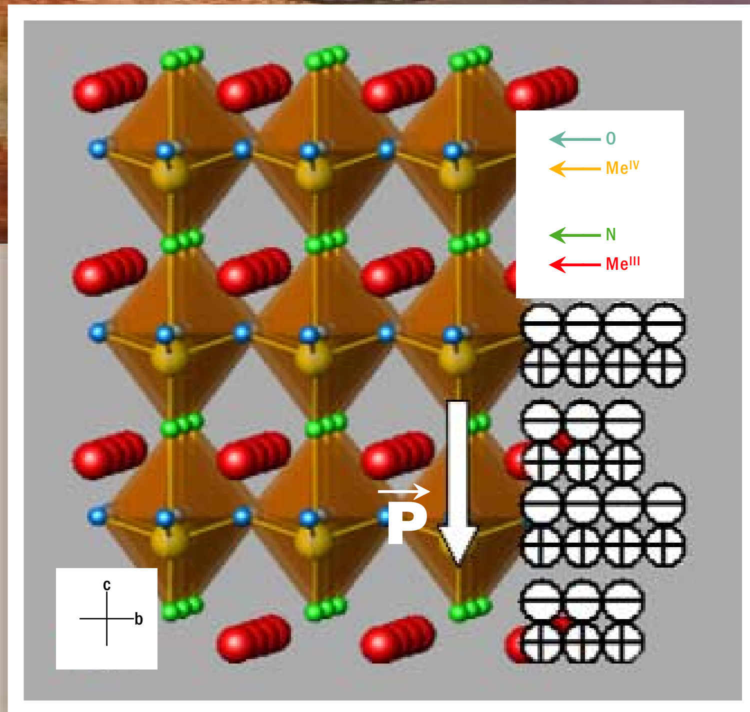
In the standard use of a piezoelectric, an electric field is applied parallel to the polarization—the field and polarization are collinear. The scientists modeled what would happen when an electrical field was applied obliquely to the direction of the polarization. They found that the polarization easily rotated, a phenomenon they dubbed polarization rotation. Cohen's team showed that this rotation is responsible for the large strain in materials called relaxor ferroelectrics. Since their prediction, dozens of lab experiments have corroborated the team's findings. It is now clear that all large coupling piezoelectrics operate through this mechanism.

Most of the ferroelectric materials today are perovskites, or perovskite-related oxides. Perovskite is a mineral with the same structure as the most common mineral in the Earth, silicate perovskite. Cohen and former Carnegie Fellow Razvan Caracas began theoretical "experiments" by changing the chemistry of these materials through substituting some of the oxygen atoms with nitrogen. They followed by changing the other atoms to obtain stable insulators (dielectrics). They designed a new class of ordered oxynitride perovskites, which have some of the largest polarization values thus far predicted or measured for any solid material. All the structures are perovskite-like or perovskite-derived, and their potential applications are manifold.



Ronald Cohen, Huaxiang Fu, and colleagues created a model for understanding the enormous piezoelectric effect of some of these important crystals. This image is a three-dimensional plot of the dependence of strain on the direction of an applied electric field of a classic ferroelectric, barium titanate ($BaTiO_3$). The bulging areas are the large strain in response to polarization rotation. The inset shows PZN-PT crystals, relaxor ferroelectric single crystals with giant electromechanical coupling.

(Image courtesy Ronald Cohen; inset courtesy TRS Technologies, Inc.)



Like well-practiced soldiers, these atoms displace to create a huge polarization effect (depicted by the big arrow with P), which is the key to a new class of superstrong piezoelectrics called oxynitride perovskites, developed by former Carnegie Fellow Razvan Caracas with staff member Ronald Cohen.

(Image courtesy Razvan Caracas.)

A Chemical Journey Back to Our Origins

For more than 4.5 billion years, comets have preserved the dust and ice left over from the formation of our solar system, making them exciting targets for research into our own origins. Seven years ago, NASA launched the Stardust mission on a 3-billion-mile journey to retrieve dust from comet Wild 2 and bring it back to Earth for analysis. On January 15, 2006, the spacecraft's sample canister touched down in the Utah desert, carrying with it the first comet samples ever studied by humans.

The micron-sized comet grains came embedded in slabs of aerogel, a special "foamed glass" that is 99.8% air by volume. The satellite gathered less than 1/1000 of an ounce of comet material. After successfully clearing the hurdle of collecting the samples and bringing them back to Earth, members of the Stardust team had to carefully sort, clean, and prepare the minuscule grains for study.

Geophysical Laboratory staff member George Cody and postdoctoral fellow Hikaru Yabuta are using the Scanning Transmission X-ray Microscope (STXM) at Lawrence Berkeley Laboratory's Advanced Light Source to analyze the organic, or carbon-based, chemistry of these samples. The STXM's remarkable optical system focuses an X-ray beam onto a spot 30 nanometers in

Former Carnegie Fellow Razvan Caracas (pictured) and colleagues are developing new materials with countless applications from medicine to defense. Caracas is now at the Bayerisches Geoinstitut, Universität Bayreuth, Germany.

(Image courtesy Razvan Caracas.)

diameter—about the size of the virus that causes the common cold. The STXM makes it possible to analyze comet particles that contain only a few hundred attograms of carbon. (One attogram equals 1 billionth of a billionth of a gram, or 10^{-18} g.)

Cody and Yabuta's preliminary work has revealed that the organic matter in comets is complex in structure and has a rich variety of nitrogen- and/or oxygen-containing functional groups—assemblies of atoms that give a molecule some of its characteristic properties. In fact, it appears that comets carry more of these functional groups than meteorites do, while also carrying fewer compounds with aromatic, or ringed, carbon structures. These preliminary results fly in the face of many astrochemical theories that predict that organic matter in a young solar system should contain abundant aromatic carbon.

If the Stardust samples from comet Wild 2 can be likened to a book on the early, low-temperature history of our solar system, then Cody, Yabuta, and other collaborators (including GL's Andrew Steele and Marc Fries, and Terrestrial Magnetism's Larry Nittler and Conel Alexander) have read only the first few chapters. Time will tell what exciting plot twists might surface in the future. •

From left to right, Susan Wirick of the National Synchrotron Light Source, George Cody of Carnegie's Geophysical Laboratory, and Tham Vu of Monash University in Australia pose with the Scanning Transmission X-ray Microscope (STXM) at the National Synchrotron Light Source, Brookhaven National Laboratory.

(Image courtesy George Cody.)

GLOBAL ECOLOGY

Exploring Ecosystems from the Smallest to the Largest Scale

Filling the Gaps in the Global Carbon Cycle

As the consequences of global climate change increasingly worry scientists and policymakers, the focus on monitoring causes and devising solutions has been directed to the industrialized nations of Eurasia and North America—the dominant sources of fossil-fuel emissions and attendant greenhouse gases like carbon dioxide (CO_2). But air has no borders. The lack of monitoring over other parts of the planet significantly impairs the ability to understand the dynamics of the entire global carbon cycle. Joe Berry and collaborators are working to define the large-scale carbon "budget" of a neglected part of the world that represents some 20% of the planet's land mass—Africa.

With 14% of the world's population but only 3% of fossil emissions, Africa poses an interesting case. In contrast to more-developed continents, most of Africa's anthropomorphic carbon emissions come from fires, land-use changes, and ecosystem degradation by overgrazing and desertification. However, without a dedicated monitoring system, the magnitude of this contribution is unknown. To date, estimates of the amount of CO_2 from Africa have been based largely on computer models, but such models yield uncertain results because of the continent's diverse and complicated ecosystems—from the Sahara Desert to savannas and jungles.

Berry, with collaborators at NASA, at Colorado State University, and in South Africa, has embarked on the continental-scale African Carbon Exchange project to help define Africa's role in this critical cycle. Vegetation uses CO_2 to grow and then releases it when it decomposes or burns. To measure how carbon wends its way between vegetation and the atmosphere, the researchers are setting up monitoring stations to catalog concentrations of CO_2 on the ground and above the tree canopy. They are also monitoring stable isotopes, forms of carbon and oxygen that differ in the number of neutrons in the nucleus. Because plants and microorganisms use and release stable isotopes in ratios that depend on vegetation type, soil characteristics, seasonal changes, short-term weather, and the composition of the atmosphere, the isotopes in the atmosphere provide telltale signs conveying vital information about how carbon, oxygen, and water are cycled through ecosystems. The researchers are also gathering high-resolution data from NASA satellites to characterize ecosystems, and all of this information helps them calibrate their computer models.

So far, there are CO_2 measurement sites in South Africa and Mali, and another will soon be located in Zambia. With existing infrastructure and technical support, other types of measurement sites will provide information to be used in combination with the project's other tools. This blend is designed to fill in information between scattered sites and to check its accuracy by comparing the measurements with the results of a model that predicts the CO_2 concentration at observation sites around the globe.

An Uncertain Future as the Oceans Turn to Acid

Sixty-five million years ago, a catastrophe of global proportions—possibly the aftermath of a colossal meteorite impact—wiped the dinosaurs from the face of the Earth. But they were not the only casualties. Fossil records also

This tower is an experimental setup for meteorological measurements of CO_2 exchange by a savanna ecosystem in Kruger Park, South Africa.

reveal a massive die-off of corals in the world's oceans, most likely the result of a drastic shift in ocean chemistry.

Now it seems that history might repeat itself. Increased carbon dioxide emissions are rapidly making the world's oceans more acidic and, if unabated, could cause a mass extinction of marine life similar to the one that occurred when the dinosaurs disappeared.

Using computer models, Ken Caldeira has predicted that the oceans will become far more acidic within the next century. He has found some startling similarities between these data and evidence from the fossil record. While the chemical effects of ocean acidification are likely to last tens of thousands of years, Caldeira estimates that biological recovery from another chemical catastrophe could take millions of years.

Some of the carbon dioxide from the burning of fossil fuels dissolves in the ocean and becomes carbonic acid, increasing the acidity of ocean water. When acid input is modest, sediments from the ocean floor can dissolve and buffer it. But at the current rate of input—nearly 50 times the natural background from volcanoes and other sources—this buffering system is overwhelmed. If current trends in carbon dioxide emissions continue, Caldeira's model predicts that high-latitude ocean waters will become acid enough to start dissolving the shells of some marine organisms.

Ocean acidification threatens all marine organisms that use calcium carbonate to make their shells, including corals. Under normal conditions, the ocean is supersaturated with this mineral, making it easy for these creatures to grow. However, an increasingly acidic ocean decreases

Walter Kubheka, a technician employed in South Africa by the project, stands by a precision gas analysis system constructed by Larry Giles at Global Ecology. The system conducts accurate measurements of CO_2 concentrations that are cross-calibrated with the global CO_2 monitoring network.

the concentration of the carbonate ion that serves as raw material for shells, putting these species at risk.

The oceans endured a similarly drastic change in chemistry roughly 65 million years ago. Many researchers believe that a meteorite smacked into what is now the Yucatan Peninsula and struck a carbonate platform rich in calcium sulfate, releasing a large amount of sulfur. This material would have later rained down on the ocean as sulfuric acid. In addition, the impact likely released carbon dioxide, which further acidified the oceans.

The fossil record reveals a precipitous drop in the number of calcium carbonate-shelled species, especially corals and plankton, in the upper ocean at this time—a pattern consistent with the effects of drastically acidified seawater. Species with shells made from resistant silicate minerals were more likely to survive.

Caldeira believes that the only remedy for ocean acidification is to cultivate nonfossil energy sources, such as wind, solar, and nuclear power, which can fuel economic growth without releasing dangerous carbon dioxide into the environment. •

Global Ecology's Ken Caldeira's work on ocean acidification was featured in an *LA Times* series called "Altered Oceans." He poses on the beach during a break from the photo shoot.

(Image courtesy Ken Caldeira.)

OBSERVATORIES

Investigating the Birth, Structure, and Fate of the Universe

The Social Life of Galaxies

Galaxies rarely stand alone—instead they tend to gather in small collections called galaxy groups. These groups can get crowded, and galaxies commonly brush up against one another. Sometimes, two galaxies get close enough to merge into a single galaxy. New evidence suggests that this phenomenon is common in the life cycle of galaxy groups, and that some groups might eventually coalesce into one large galaxy.

In the mid-1990s, astronomers discovered groups that emit X-rays. Using the space-based X-ray telescope ROSAT, John Mulchaey and collaborators showed that this radiation is spread over the entire volume of a group—several hundreds of thousands of light-years. This result suggests that X-rays originate in low-density gas heated to about 10 million degrees. At these temperatures, gas should quickly disperse unless it is confined by another force.

Astronomers believe this force is gravity. However, it would take an immense amount of mass to generate the gravity required to confine this gas—far more than the matter visible in groups. This finding led Mulchaey and team to deduce that galaxy groups contain dark matter, the elusive material that exerts a strong gravitational pull but does not emit light.

Mulchaey has undertaken the most detailed study of galaxy groups yet. He has found that only about 20% of groups actually emit X-rays, making it a relatively rare phenomenon. He believes that all groups contain gas, but that the gas is too cool to produce X-rays in most cases. Using the Magellan telescopes, Mulchaey found that X-ray–emitting groups contain mostly old, red galaxies, while the nonemitting groups include many young, blue galaxies.

Mulchaey has proposed an evolutionary sequence for groups. At first, they contain many gas-rich galaxies, but over time these galaxies merge and use up some of their gas reservoirs in the production of new stars. The resulting groups are mostly made up of old, red galaxies. They also increase in mass as they age, and eventually produce enough gravity to retain high-temperature, X-ray–emitting gas. Some such groups may continue growing and merging until they form a single enormous galaxy.

In the last few years Mulchaey has discovered several of these galaxies, which he calls fossil groups. His work offers a window into the future of our Milky Way galaxy, which is part of a small group in the early stages of formation; it is likely that we will one day merge with the Andromeda galaxy, our biggest neighbor.

Chemical Archaeology of the Heavens

Our bodies and the world we live in are intimately connected to stars. Although the lightest elements—hydrogen, most of the helium, and traces of lithium—were made in the Big Bang, some 14 billion years ago, nearly all of the remaining elements were produced by nuclear reactions inside stars.

When stars die, either by spectacularly violent supernova explosions or by a gradual detachment of the stellar envelope, they return newly synthesized elements to the interstellar gas clouds. As successive generations of stars form out of these gas clouds, the fraction of new elements (sometimes referred to as the metal content) increases with time.

Thus, the overall metal content and the detailed chemical abundance patterns form a "fossil" record of chemical evolution. Andrew McWilliam and collaborators are studying the origin and evolution of the chemical elements by looking at the composition of the envelopes of long-lived stars. Their observations, made with the Magellan Inamori Kyocera Echelle (MIKE) spectrograph on the 6.5-meter Clay telescope at Carnegie's Las Campanas Observatory, are refining theoretical models, which until now have relied heavily on the composition of the Sun and its nearby neighbors.

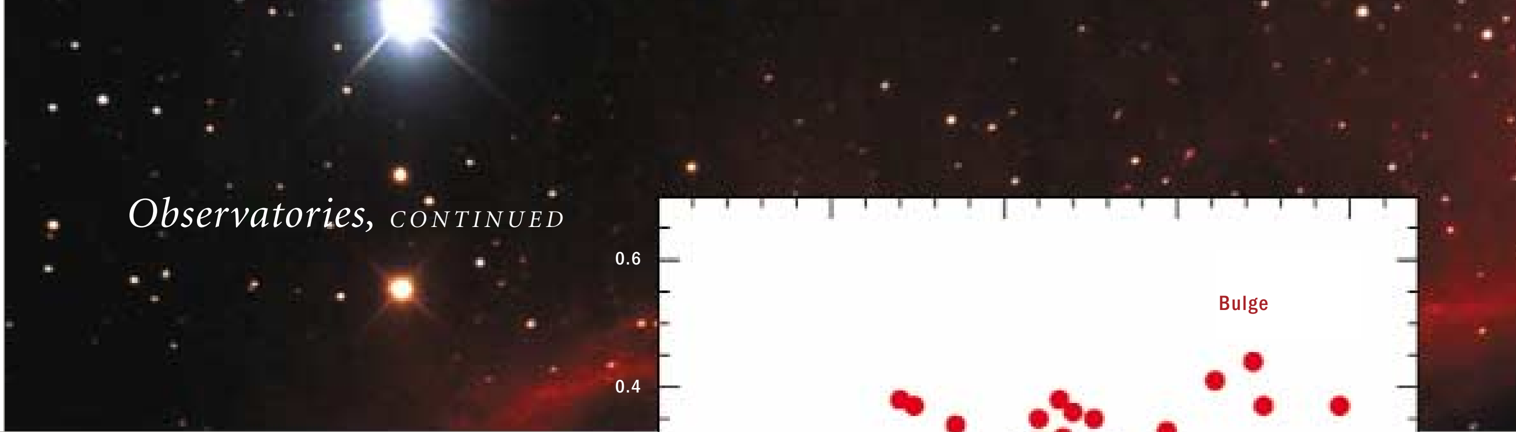
McWilliam's results show that the galactic bulge is strongly enhanced in products from supernovae events of especially massive stars. As these objects careened toward a self-destructive core collapse they produced many elements, including oxygen, aluminum, silicon, calcium, and titanium, that are characteristic of an origin from short-lived progenitor stars. These signatures suggest that the bulge evolved very quickly, in less than 500 million years. The research also shows a surprising decrease in oxygen relative to magnesium. The astronomers believe the depletion is due to "winds," or gas outflows, from

This Hubble Space Telescope (HST) image above shows the nearby Stephen's Quintet group of galaxies; it is representative of interacting galaxy groups.

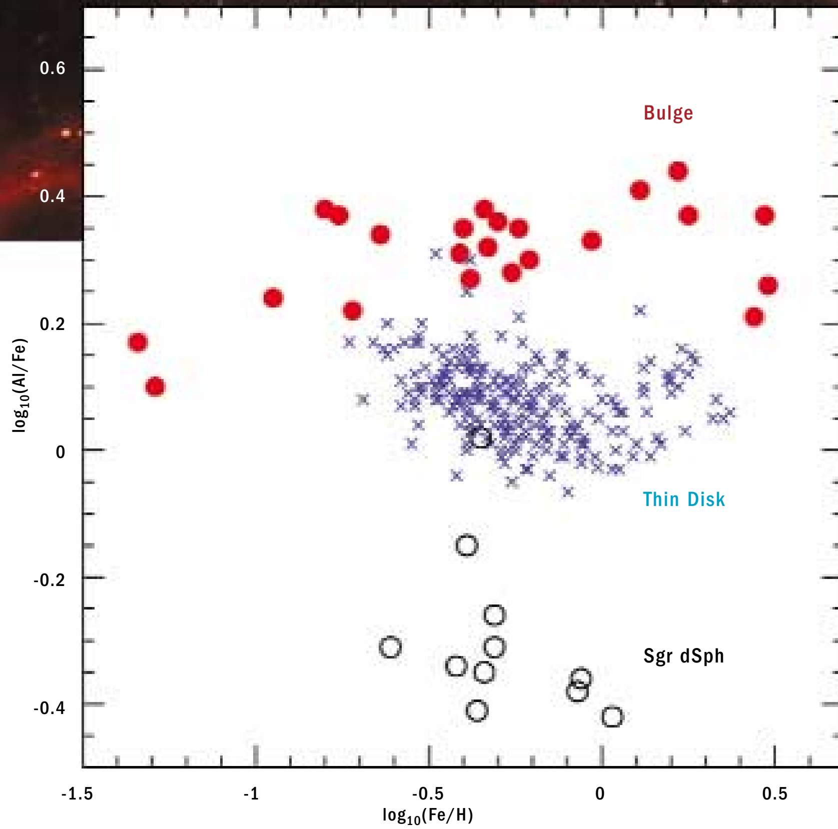
(Image courtesy Space Telescope Science Institute.)

This image below depicts the first discovery of X-ray emission in galaxy groups. It shows X-ray emission (pink) overlaid on an optical image of the NGC 2300 group of galaxies.

(Image courtesy John Mulchaey and NASA.)



Observatories, CONTINUED



The figure compares the trend of the aluminum to iron ratio (in solar units) versus metal content (measured by iron/hydrogen) in the Milky Way's bulge and thin disk, and the Sagittarius dwarf galaxy. The different chemical path taken by these systems is due to the decrease in aluminum to iron yield as the formation time increases. These results present much-needed observational clarity on theoretical nucleosynthesis and chemical evolution models, which until now relied heavily on the composition of the Sun and nearby stars.

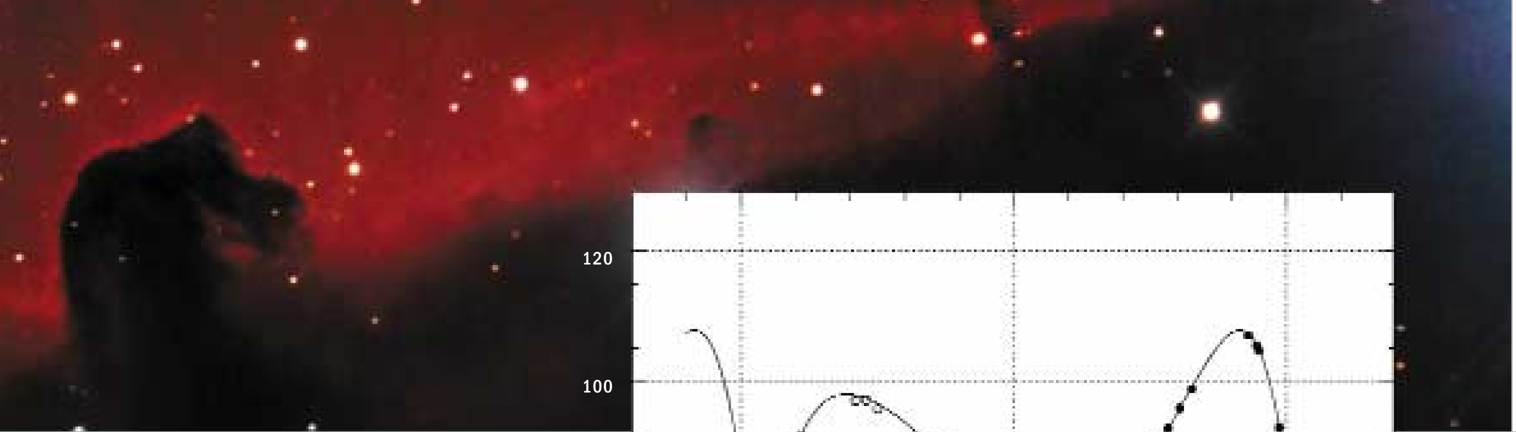
(Image courtesy Andrew McWilliam.)

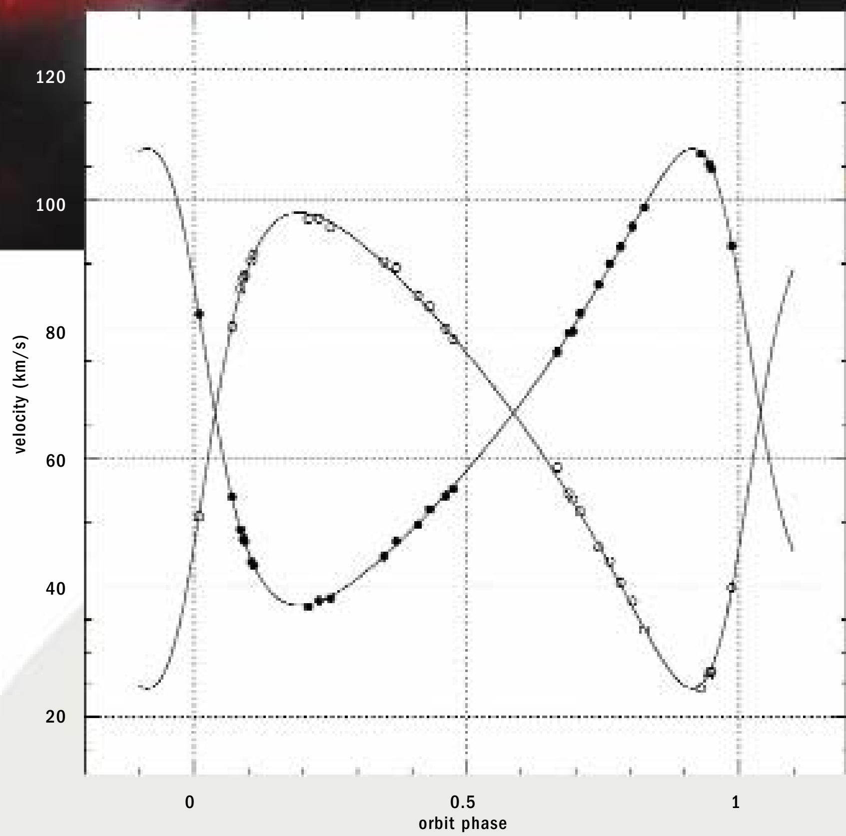
massive metal-rich stars. Although the winds are understood somewhat, they have thus far been omitted from models of supernova nucleosynthesis.

McWilliam also looked at stars in the Sagittarius dwarf galaxy, which is currently colliding with our galaxy. These stars show a paucity of products from core-collapse supernovae, but have strong signatures from a different process called slow neutron capture, where an atomic nucleus collides with a neutron to form a heavier nucleus. Because slow neutron capture elements, such as barium and lanthanum, are predominately produced by very long-lived stars, the enhancements indicate that this galaxy chemically evolved over several billions of years. Details of the pattern of neutron-capture element abundances indicate that the Sagittarius dwarf galaxy must have lost a significant fraction of its initial mass during its evolution.

Unlocking the Secrets of Elusive Double Stars

Since the beginning of humankind, people have peered into the night sky and wondered how the universe began. Some astronomers grapple with this question by studying how stars form, evolve, and die. Ian Thompson explores stellar evolution by measuring the fundamental properties of stars—their masses, luminosities, and radii—in very rare systems called detached eclipsing binary stars. These are systems in which two stars orbit each other in an orbital plane along our line of sight. While such observations have been made for many young stars in our galaxy, until this research none of these binaries had been found among so-called population II stars, the oldest stars in the Milky Way. Thompson, with colleagues, has found 16 of these binary systems in eight southern





How do astronomers measure the masses of old binary stars? This figure shows the velocities for the variable V23900 in the globular cluster M4. Since the inclination of the orbit is known, the masses can be determined from the amplitudes of the two velocity curves and the period of the orbit. V23900 has a period of 48.2 days, and the masses are 0.75 and 0.72 the mass of our Sun. This data set is the first empirical collection of luminosities, radii, and masses for these objects, a milestone in understanding stellar evolution.

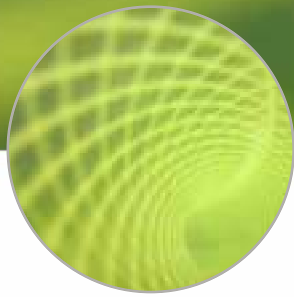
galactic globular clusters, ancient spherical systems of more than 100,000 stars each.

Astronomers need to know a star's mass, radius, and brightness to study and test theoretical models of stellar evolution. Observations of binary systems provide a means to determine these data. When one star passes in front of the other, the total light changes, and the shape of the plot is used to discern the relative sizes and separation of the stars. Thompson and team then derive the absolute dimensions of the system, and the radii and masses of the two stars, by measuring the stars' velocities and by applying Kepler's laws of gravity. They determine total and apparent luminosities by relying on a relation between the surface brightness of the star and its color, as measured in the visible and infrared regions of the spectrum. The total luminosity of the star is derived from its radius and its surface brightness, and the distance is calculated by comparing this total luminosity with its apparent luminosity. Finally, the ages of the stars can be ascertained if they find that one of the stars is at the end of its main sequence life; this period is a function of the star's mass.

Using a suite of telescopes at Carnegie's Las Campanas Observatory, Thompson and colleagues have studied these evasive systems for several years. With the Swope 1-meter telescope they are monitoring a sample of nearby southern globular clusters to detect the stellar eclipses and define their orbital periods. They use the du Pont 2.5-meter telescope to capture the changing light during the eclipse, and they harness the Magellan Inamori Kyocera Echelle spectrograph to observe stellar velocities. They plan to study similar stellar systems in the Large Magellanic Cloud, a southern galactic neighbor of the Milky Way. •

PLANT BIOLOGY

Characterizing the Genes of Plant Growth and Development



A Better Understanding of Botanical Bodybuilding

Unlike many animals, plants cannot depend on a skeleton to help them keep their shape. Instead, they stand up straight by building stiff walls around their cells, each of which is tightly glued to its neighbors. The cells within maintain a steady fluid pressure that presses against the walls, keeping the whole cell rigid in much the same way an inner tube keeps a bicycle tire inflated. It is difficult for a plant cell to change its shape once it is in place, so plants rely on carefully organized cell division and growth during development.

Plant Biology director Christopher Somerville studies how plant cells weave together a variety of molecules—mostly large, fibrous carbohydrates such as cellulose—to make and arrange their cell walls. Although these molecules make up more than half of the land-based biomass on Earth, researchers know surprisingly little about how plants manufacture them, and how their chemistry contributes to the function of cell walls.

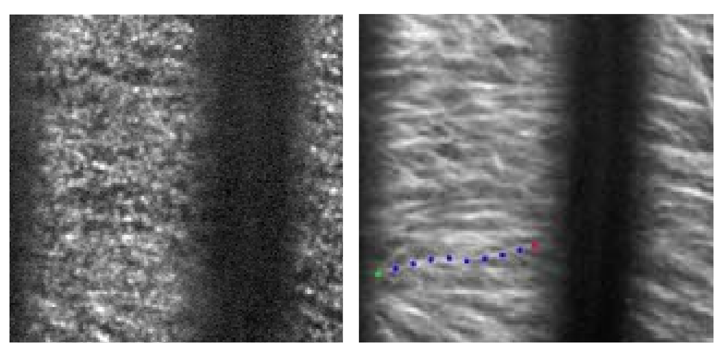
Cellulose, by far the most abundant of cell wall components, consists of about 36 parallel chains of glucose that form long microfibrils. These polymers, which can reach more than 10 micrometers in length, wrap around the surface of plant cells as they form outside the cell membrane. The fibers are extremely strong and durable, and provide much of the cell wall's resistance to expansion.

Somerville, with graduate student Alex Paredez and staff member David Ehrhardt, engineered a plant that produces fluorescent cellulose synthase—part of the enzyme complex that makes cellulose. As a result, the team could watch while individual complexes actively made cellulose in living cells. With a different fluorescent marker, the team also labeled proteins in the cortical microtubules—the scaffolding that helps to shape actively dividing cells.

By simultaneously visualizing both types of proteins, the group determined that the position and orientation of the microtubule scaffolding largely controls where and in what direction the cellulose synthase complex makes cellulose. So far, they are unsure of exactly how the microtubules guide the enzyme complexes, but it seems likely

This pair of images shows fluorescently labeled cellulose synthase—the enzyme that makes cellulose—at work in live cells. Left, an average of five images of the cell membrane taken 10 seconds apart shows the position of individual cellulose synthase complexes. (The particles are actually much smaller than they appear in the image.) Right, an average of 61 images shows particles movement during a 10-minute span; the colored dots highlight the track of a single enzyme complex. The researchers determined that a single enzyme complex links gluclose molecules into cellulose fibrils at the rate of nearly 25,000 per minute.

(Image reprinted with permission from Science *312, 1491-1495, 2006.)*



Some members of The Arabidopsis Information Resource (TAIR) team (left to right) are Julie Tacklind (Webmaster), Margarita Garcia-Hernandez (curator), Eva Huala (director), and Sue Rhee.

(Image courtesy Sue Rhee.)

they are in direct contact with each other.

Somerville and Ehrhardt's research groups are now studying cellulose formation from two different, yet complementary, angles: Somerville's team is working to understand the cellulose synthase complex, and Ehrhardt's crew is focused on the organization and orientation of the microtubules. Together the groups hope to discover the functional relationship between the two structures. While a better understanding of cellulose formation will certainly lead to a better understanding of plant growth, it might also aid the effort to produce biofuels from cellulose.

Cultivating Plant Data in the Information Age

TAIR (The Arabidopsis Information Resource), a biological database directed by Plant Biology's Seung (Sue) Rhee, is an information age tour de force. *Arabidopsis*, a relative of the mustard plant, is the most widely used research plant today. Developed by Rhee and colleagues at Carnegie and the National Center for Genome Resources, TAIR is among the most accessed "bioinformatics" resources in all of biology. Although the database focuses on *Arabidopsis*, it also helps researchers understand the genes governing growth, development, disease, and more in all plants. The database has grown from 100,000 page hits per month in 2000, to 1 million per month in 2005. Rhee's work has helped set the standard for biological databases worldwide, and she is now mining the information to conduct plant experiments without actually growing a thing.

TAIR is accessible via commonly used Web browsers (http://www.arabidopsis.org/). Researchers can review the *Arabidopsis* literature and find information about genes, genetic markers, nucleotide sequences, clones, proteins, gene families, biochemical pathways, researchers, notes, and can even order seed and DNA stocks using an online shopping-cart system. The database's flexible architecture allows Rhee and colleagues to adapt it as more information is learned about plants and the relationships among their molecular components.

In addition to directing TAIR, Rhee is leading the charge for improving and standardizing the vast array of bioinformatics resources. Currently, different biological databases have inconsistent nomenclature, organization, annotation, and displays. Rhee seeks a seamless connection among related databases, public repositories, and journals in an effort to make the data explosion more accessible to biologists all over the world.

Rhee sees the future of bioinformatics as a primary source for virtual experiments. Toward this end, she and colleagues have been using the enormous databank to

investigate the molecular mechanisms of plant responses to environmental stresses, such as excess salt, drought, wounds, cold, heat, and more. Using the bioinformatic infrastructure she developed and in collaboration with others, she started to tackle the problem by analyzing data from experiments that use state-of-the art technologies such as microarrays. Preliminary results from her statistical analyses show that the genes affected by these stresses fall into two general types. She foresees using the data to model the network of regulatory molecules that govern how genes are turned on and to identify the regulatory genes that control the biochemical processes that enable plants to adapt and respond to changes in the environment. To corroborate the findings, she will verify her virtual experiments by testing actual plants.

Genetic Defenders on the Front Lines

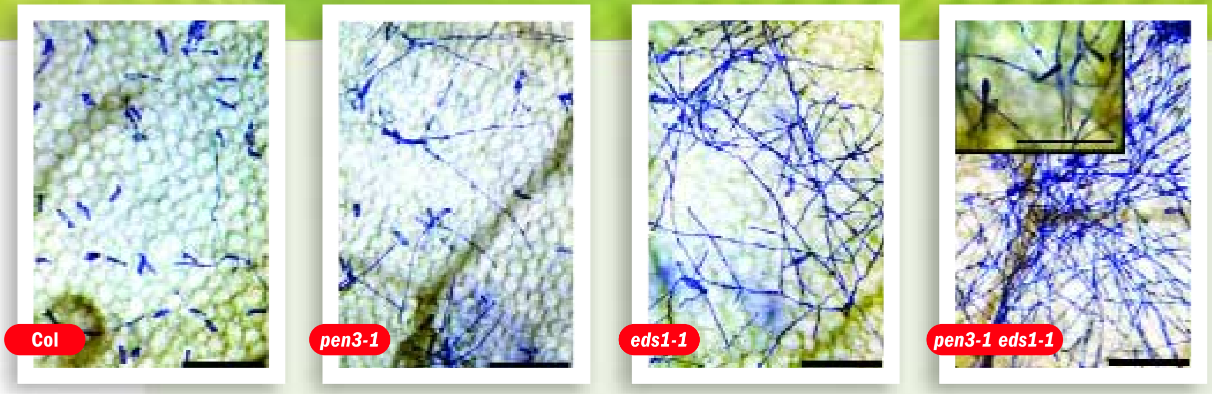
Like soldiers guarding a castle gate, multiple genetic defenders protect plant cells against powdery mildew disease—a common fungal infection that attacks more than 9,000 plant species, including important crops and horticultural plants. Shauna Somerville, postdoctoral fellows Laurent Zimmerli and Matt Humphry, and graduate student Monica Stein of Carnegie's Department of Plant Biology are among the first to document these defense genes in plants. Their discovery could help combat fungal pathogens and save billions of dollars in pesticides and crop losses every year.

Each species of powdery mildew can infect some plant species but not others. Somerville and Zimmerli discovered that a species of powdery mildew that attacks the mustard relative *Arabidopsis thaliana* works by somehow suppressing (or failing to activate) a common defense pathway. Another mildew species that normally infects barley, however, is unable to suppress this pathway. Somerville, Stein, Humphry, and colleagues built on this work by disabling certain protective genes in *Arabidopsis*; as a result, they were able to infect these plants with the barley mildew as well as another type that normally attacks pea plants. Identifying these genes has provided crucial insight into how plants defend against multiple pathogens.

Once a powdery mildew infection takes hold, it covers the plant with fuzzy splotches, and the fungal spores invade healthy plant cells with rootlike feeding structures that sap precious nutrients. A suite of defense genes called *PEN1*, *PEN2, PEN3,* and *MLO2* prevent the fungus from penetrating the cells' first line of defense: the cell wall.

Depending on the mildew species, some mildew succeeds in breaking through the cell wall in about 5% to 25% of normal *Arabidopsis* cells. At this point a complex of three genes, *EDS1*, *PAD4*, and *SAG101*, can signal infected cells to die. By sacrificing these fallen cells, the defense genes can spare healthy ones from infection.

Somerville, Stein, and colleagues at the Max Planck Institute for Plant Breeding in Cologne disabled the protective genes in *Arabidopsis* by introducing mutations in various combinations. They infected these mutants with one of two species of powdery mildew, one that attacks barley and one that attacks pea plants. The pea powdery



These micrographs show *Arabidopsis* leaves inoculated with the fungal parasite *Erysiphe pisi*, which is stained blue in this image. From left to right, plants with no mutations (Col), a disabled *PEN3* gene (*pen3-1*), a disabled *EDS1* gene (*eds1-1*), and both genes disabled together are increasingly vulnerable to the fungus. The last variant of *Arabidopsis* is the most susceptible to infection; it allowed *E. pisi* to reproduce, thus completing the pathogen's life cycle.

(Image reprinted with permission from Plant Cell *18, 731-746.)*

mildew reproduced as well on triple-mutant *Arabidopsis* as on its normal host, suggesting that resistance barriers rely on just a limited number of genes.

The *EDS1*, *PAD4*, and *SAG101* gene complex's ability to signal cell death was relatively well known to scientists. However, very little was known about how the *PEN* genes function. The researchers demonstrated that the PEN3 protein is a transporter—a protein that exports molecules to the cell wall—although the molecules it transports remain unknown. Their research expands on previous work on *PEN1*, which seems to share a common purpose with *PEN3*. However, *PEN3* appears to protect against a wider range of fungal pathogens; for example, *PEN3*-mutant *Arabidopsis* is more susceptible than normal plants to *Phytopthora infestans*, the fungus responsible for the notorious Irish Potato Famine of the mid-19th century.

The genetic mechanisms that protect plants from fungal pathogens appear to be relatively simple, relying on only a handful of genes. It might be possible to engineer crops with these hardy *Arabidopsis* genes to help control powdery mildew and other destructive diseases, thus minimizing the need for pesticides. •

TERRESTRIAL MAGNETISM

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

One Natural Force Provokes Another: Typhoons and Slow Earthquakes in Taiwan

Eastern Taiwan experiences relatively few massive, headline-grabbing earthquakes, despite being one of the most rapidly deforming tectonic regions on Earth. New research has revealed that “slow” earthquakes—subtle tectonic shifts that last for hours or even days and do not show up on standard seismographs—relieve some of the strain built up as the Philippine Sea Plate forces itself west into and beneath the Eurasian Plate. Unexpectedly, it seems that these slow quakes can be triggered by typhoons—tropical storms that originate in the western Pacific Ocean.

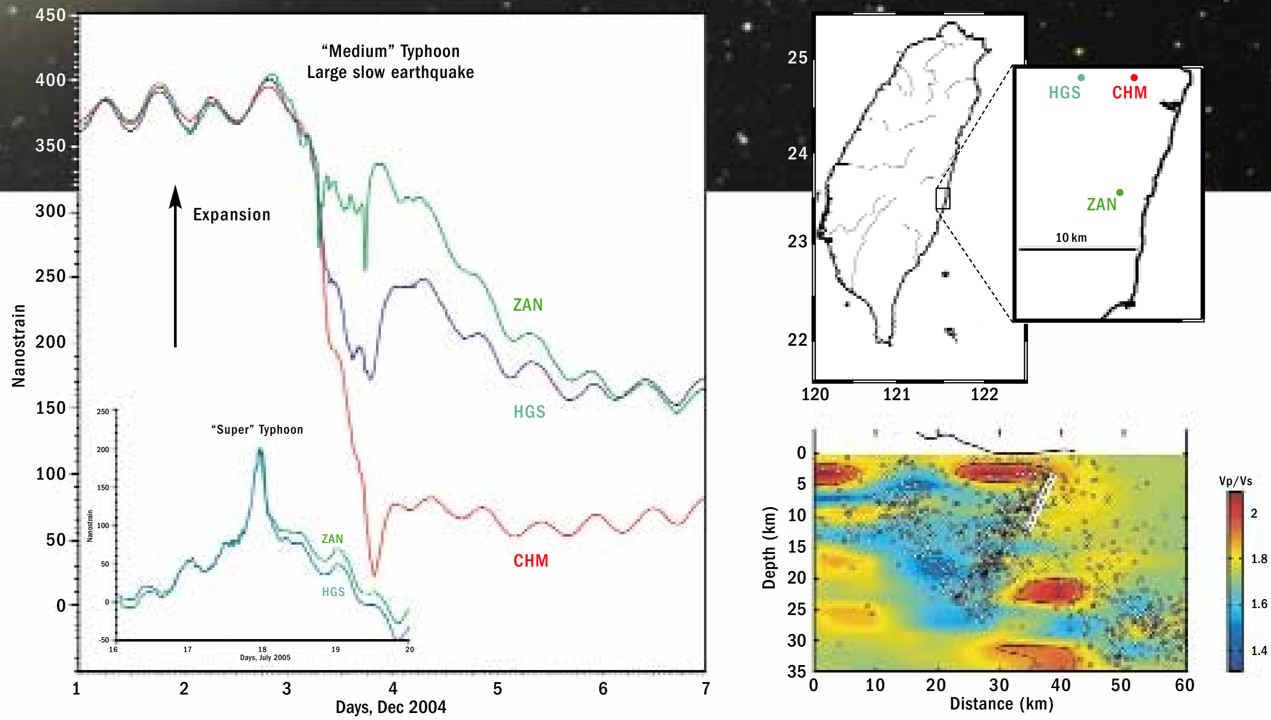
To study the fault system, Selwyn Sacks and Alan Linde of the Department of Terrestrial Magnetism (DTM) and their team installed a small network of strainmeters—devices embedded in boreholes that can track otherwise imperceptible distortions in rock—beginning in 2003. The project is in collaboration with Chi-Ching Liu of the Academia Sinica in Taipei.

Global Positioning System data have revealed that eastern Taiwan’s Longitudinal Valley narrows by nearly an inch per year along a 6-mile section of the coast, building up a great deal of strain in the process. By contrast, the deformation along the San Andreas Fault in California is spread over a distance at least 10 times larger. Strain meter data have shown that some of the strain in the Longitudinal Valley is released via slow earthquakes. Sacks, Linde, and Liu were surprised to find that these quakes seemed to occur when typhoons made landfall near the fault. It became clear that this was far more than just coincidence; the typhoons were, in fact, triggering the quakes.

DTM instrument maker Nelson McWhorter (front) checks a strainmeter before it is transported to the study site for installation in Hualien, eastern Taiwan. Selwyn Sacks (DTM, middle) and Chi-Ching Liu (Academia Sinica, left) check the electronic components.
(Image courtesy Alan Linde.)

The explanation lies partly in the nature of typhoons and partly in the geometry of the eastern Taiwan fault system. A typhoon is not only a potentially deadly cyclonic juggernaut; it is also a slow-moving zone of low atmospheric pressure. The relevant fault in eastern Taiwan traces the coastline, with one side of the fault on land and one under the sea.

As a typhoon passes over the fault, it reduces the atmospheric pressure on land. This change in atmospheric pressure does not affect the pressure at the bottom of the ocean



These figures show the effect of typhoons on a section of the Longitudinal Valley fault in eastern Taiwan. At left, strainmeter data show that typhoons cause a decrease in atmospheric pressure, which results in expansion of the rock. The inset graph depicts a typhoon in mid-July 2005; the lower-pressure eye of the hurricane can be seen as peaks in the middle of the graph. The larger graph shows a typhoon in December 2004 that triggered a slow earthquake; the shift in the fault resulted in compression at the strain-measuring stations, as seen in the dip in the strain traces. At bottom right, a vertical section through the fault area shows the orientation of the fault, which dips 65° westward. Black dots indicate earthquake locations, colors denote different ratios of the speeds of compressional (P) and shear (S) waves, and the dashed line shows the path of the December quake, which began less than 2 miles (~3 kilometers) below the surface and spread to a depth of over 6 miles (~10 kilometers). At top right, the map shows the study area with strainmeter locations labeled.

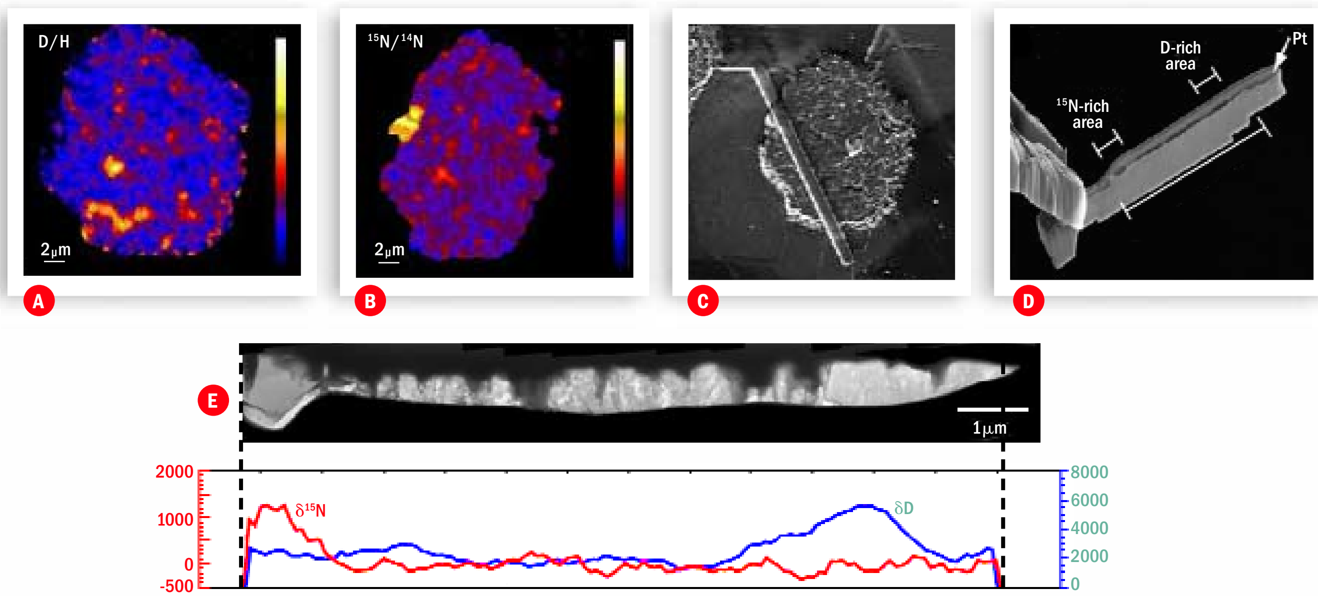
because water moves to equalize the pressure; only the land side of the fault experiences a significant pressure drop.

Depending on how much strain is stored in the fault, this one-sided decrease in pressure can cause a slow earthquake. High levels of strain make it more likely that the fault will "unclamp," resulting in slippage. Earthquake or not, the changes in strain are easily detected by the strainmeter network. The data reveal that four of nine typhoons during a yearlong study triggered significant slow earthquakes; these four typhoon-triggered quakes were the only ones that occurred during this time.

Sacks, Linde, and Liu speculate that typhoons could account for the peculiar rarity of big earthquakes in eastern Taiwan. The frequent storms on the island might trigger many subtle temblors, which could act as "pressure valves" to relieve much of the tectonic stress in the fault system. In this case, the fault would rarely build up enough strain to power a major earthquake.

Survival of the Fittest: Organic Matter from the Ancient Solar System

Spectacular shooting stars that make it to Earth—meteorites— are fragments of objects originating in the asteroid belt located between Mars and Jupiter. Meteorites bring extraterrestrial materials to our planet including, some believe, the building blocks of life—complex organic material. Now, Henner Busemann, Larry Nittler, and Conel Alexander at DTM, with colleagues, have found the best evidence yet that at least some organic particles in meteorites originated in interstellar space or, perhaps,



These images show different analyses needed to understand the origin of insoluble organic matter from very ancient meteorites called carbonaceous chondrites. The bright yellow spots on image A indicate the amount of heavy hydrogen (D) relative to the lighter hydrogen isotope (H). On image B, the glows indicate the higher abundance of the heavy isotope of nitrogen ^{15}N relative to ^{14}N. The relative proportions of hydrogen and nitrogen isotopes point to how and where the meteorite organic matter was generated. Image C is a scanning electron microscope image of a tiny fragment held in place with a microscopic strap before the sample is cut. Microscopic tweezers (left on image D) hold an ultrathin section of the material, which was extracted by a focused ion beam. Image E was produced by transmission electron microscopy (TEM), in which a beam of electrons passes through a specimen, resulting in a high-resolution image. It is aligned with a graph profiling the ratios of the hydrogen and nitrogen isotopes.

(Image courtesy Henner Busemann, Rhonda Stroud, and Tom Zega.)

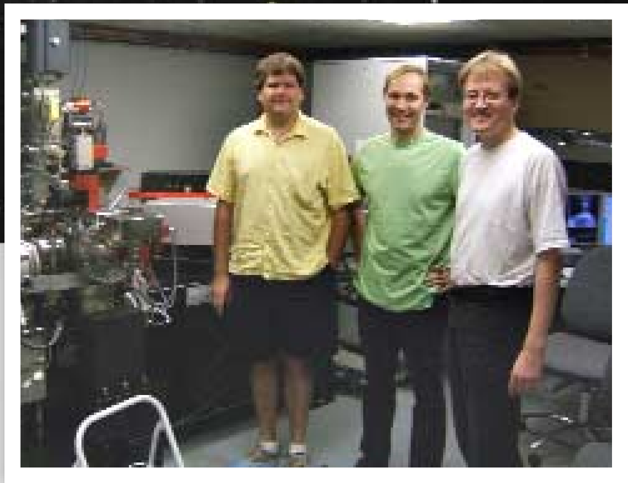
in the cold, outer solar system as it was beginning to coalesce from gas and dust some 4.5 billion years ago. Their work also suggests that organic matter in asteroids is more closely related to that in comets, which formed much farther out in the solar system than scientists had previously thought.

The key to these discoveries was the team's use of novel techniques to analyze, at minute scales, the isotopic compositions of organic material from some of the most primitive meteorites known. Isotopes are different forms of an element's atoms. The relative proportions of an element's isotopes in the organic matter depend on formation conditions, such as temperature and chemical reactions.

In this work, the relative proportion of isotopes nitrogen (^{14}N and ^{15}N) and hydrogen (H and D) provide clues to how and where the meteorite organic matter was generated. The telltale sign of primitive organics is the high abundance, relative to terrestrial materials, of the heavy isotopes of hydrogen (deuterium, or D) and nitrogen (^{15}N) chemically bonded to the carbon.

Tiny interplanetary dust particles (IDPs) collected in the Earth's upper atmosphere often contain huge excesses of these isotopes, which points to the formation of their organic matter in the interstellar medium. IDPs also have characteristics indicating that they come from comets, and therefore experienced less severe processing after formation than did the asteroids from which meteorites originate.

Busemann and team found that their meteorite samples, when examined at the same tiny scales as interplanetary dust particles, have similar or even higher abundances of ^{15}N and D than those reported for IDPs, which suggests that asteroids and comets may belong to the same family tree. The team will further test this result via their analyses of the samples recently returned by the Stardust mission from comet Wild 2.



Department of Terrestrial Magnetism scientists Larry Nittler, Conel Alexander, and Henner Busemann (left to right) stand in front of the NanoSIMS ion probe. Ion probes can reveal the chemical makeup of a sample by vaporizing tiny target areas with a stream of ions. The NanoSIMS allows a more accurate count of the elements emitted than previous ion probes and is ideal for analyzing minuscule grains from meteorites, interstellar dust particles, and comets, such as those from Wild 2 obtained via the Stardust mission.

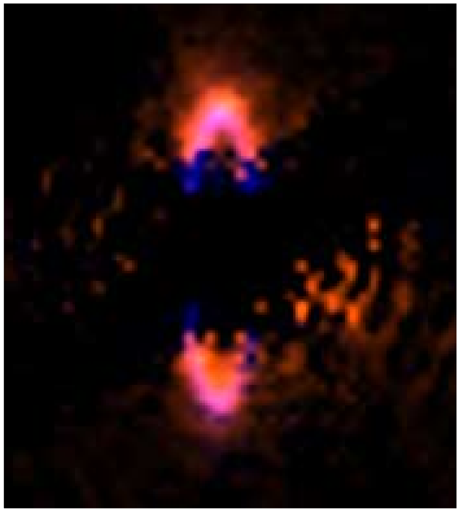
(Image courtesy Henner Busemann.)

Can Dusty Disks Beget Other Earths?

As gas, dust, and rocky chunks swirled around the Sun during the first few tens of millions of years of our solar system's history, comets or asteroids ferried life-giving water and possibly complex hydrocarbons to the young Earth. To understand what leads to life-bearing worlds, Alycia Weinberger and colleagues look to distant stars and their young planetary systems—circumstellar disks of dust and gas. Weinberger and coworkers are deciphering the composition of these disks and are determining whether the ingredients for life are present. It turns out that Earth's chemistry might not be that rare.

Dust and gas in circumstellar disks reflect or absorb the light from their stars in specific ways. Different

Terrestrial Magnetism, CONTINUED



This young disk system around star HR 4796A appears red, which suggests the presence of long organic chains, possibly similar to the tholins found in the red rings of Saturn and in the atmosphere of its moon Titan. The color indirectly suggests the possibility of methane ice, such as that believed to be on the surface of a distant icy body in our own system named Centaur Pholus 5145.

(Image courtesy John Debes, Alycia Weinberger, and Glenn Schneider.)

Department of Terrestrial Magnetism astronomer Alycia Weinberger at Carnegie's Las Campanas Observatory

(Image courtesy Alycia Weinberger.)

molecules, such as water and methane ices, can coat the dust and reflect light at characteristic wavelengths. Carbon-rich materials can appear red and not very reflective, for instance. By analyzing the light from a distant disk around HR 4796A, a 10-million-year-old star some 2.5 times as massive as the Sun, Weinberger, postdoctoral researcher John Debes, and their team recently found it to be very red and dark, indicating the presence of organic materials. They suspect long organic chains similar to the tholins found in the red rings of Saturn and in the atmosphere of its moon Titan—a promising location in the search for life. The results also closely match the color of a distant icy body in our own system named Centaur Pholus 5145, believed to have a surface composed of water and methane ice—more evidence hinting that HR 4796A may be able to produce Earth-like planets.

Other evidence for this rich, carbon chemistry comes from Beta Pictoris, a star that is a little less massive and just a bit older than HR 4796A. For years, it has been known that small orbiting bodies break up to enrich the disk in gas and dust. Using NASA's Far Ultraviolet Spectroscopic Explorer and the Hubble Space Telescope, former Carnegie Fellow Aki Roberge, with Weinberger and colleagues, analyzed the disk's gas and detected unusually high quantities of life-essential carbon, more than in our solar system's comets and asteroids or in the star itself. The researchers pose several possible explanations for this abundance: the vaporization of unusually carbon-rich asteroids or comets; the difference between young and old comets and asteroids, where the young may be more carbon rich; or evaporation from cold methane-rich bodies.

For more tantalizing clues to early solar system chemistry, Weinberger and colleagues have embarked on new programs using the Spitzer Space Telescope, the Hubble Space Telescope, and Carnegie's Las Campanas Observatory to find other young solar systems potentially amenable to extraterrestrial life. •

FIRST LIGHT & THE CARNEGIE ACADEMY FOR SCIENCE EDUCATION

Teaching the Art of Teaching Science

Science Education at CASE: Full Steam Ahead

The Carnegie Academy for Science Education's (CASE) venture into the secondary school arena received a huge boost in 2006. The Division of Undergraduate Education of the National Science Foundation (NSF) awarded it an $820,000 three-year grant to support D.C. Biotech: Improving Opportunities for Urban Minority Students. The project is designed to improve science competencies of D.C. high school students through biotechnology certification, the broadening of students' career opportunities, and the improvement of biotech workforce diversity. CASE is the lead organization in developing the program. Other consortium members include the D.C. Public Schools (DCPS) Office of Career and Technical Education, McKinley Technology High School, Ballou Senior High School, Montgomery College, the Biotechnology Industry Advisory Committee, Walter Reed Army Medical Center, and numerous other regional research and educational institutions.

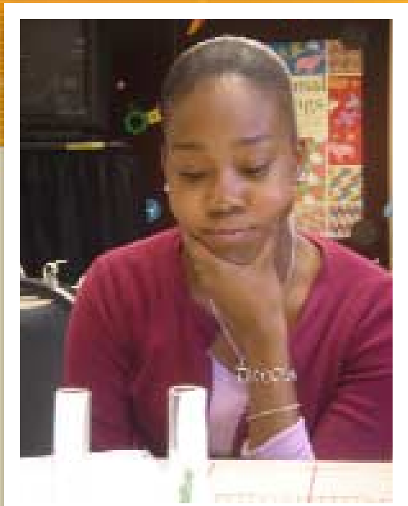
The CASE summer 2006 program had some new dimensions. It marked the second year in which D.C. elementary school teachers, formerly trained by CASE, successfully "soloed" in the teaching of other D.C. public school teachers in the art of teaching science, mathematics, and technology. Maxine Singer, Carnegie president emerita and CASE senior scientific advisor, designed and taught the second year of a program that was developed by CASE for middle school science and math teachers.

The new program is designed to teach science through the study of astrobiology, a multidisciplinary examination of the chemical and biological conditions that led to life on Earth and the circumstances that are most likely required for it to exist elsewhere. Teachers learned through experimentation, field trips, and classroom visits by Carnegie astrobiologists Paul Butler and Marilyn Fogel. Following CASE's long tradition of nurturing outstanding mentor teachers, a 2005 Astrobiology Institute alumnus, Guy Brandenburg, cotaught the 2006 institute with Singer.

President emerita and senior scientific advisor to CASE Maxine Singer (left) shows middle school teacher Martha Harris laboratory techniques during the 2006 Astrobiology Institute.

First Light & the Carnegie Academy for Sciene Education, CONTINUED

CASE codirectors Toby Horn and Julie Edmonds are principal instructors in the D.C. Biotech summer work experience. The students are paid by the D.C. Government's Department of Employment Services as part of its summer employment program for teens. Some 24 rising juniors and 16 rising seniors from McKinley Technology High School, as well as five DCPS teachers, learned biotechnology workplace practices and procedures. With coteachers from DCPS, Horn instructed the seniors, while Edmonds and coteachers taught the juniors. The juniors learned basic biotech skills that culminated in weeklong group projects—either forensic DNA fingerprinting or deciphering the concentrations of pigments in soft drinks. The seniors worked on numerous projects throughout the summer. Some chose to investigate the best conditions needed to cut DNA specifically or to determine which vegetable seeds could germinate in high-salt conditions, while others compared the sensitivity of different forensic tests or looked at the effect of purified yogurt bacteria on protein patterns of milk whey. All of the students used state-of-the-art laboratory equipment, rarely seen in high school labs, purchased for the school by the DCPS Office of Career and Technical Education. •



(Top) Middle school teacher Kendra Neal compares chlorophyll chromatography patterns during the 2006 Astrobiology Institute.

(Bottom) Rising senior Monica Artis shows visitors a protein assay as part of the D.C. Biotech project open house. From left to right are Monica Artis; Moses Shanfield, chairman of Forensic Science at George Washington University; and David Hanych, project director at NSF.

(Images courtesy Toby Horn.)

FINANCIAL PROFILE & FINANCIAL STATEMENTS AND SCHEDULE

READER'S NOTE: In this section, any discussion of spending levels or endowment amounts is on a cash or cash-equivalent basis. Therefore, the funding amounts presented do not reflect the impact of capitalization, depreciation, or other non-cash items.

FINANCIAL PROFILE *for the year ending June 30, 2006*

The Carnegie Institution of Washington completed fiscal year 2006 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 support of organizations and individuals who recognize the wisdom of nurturing basic science.

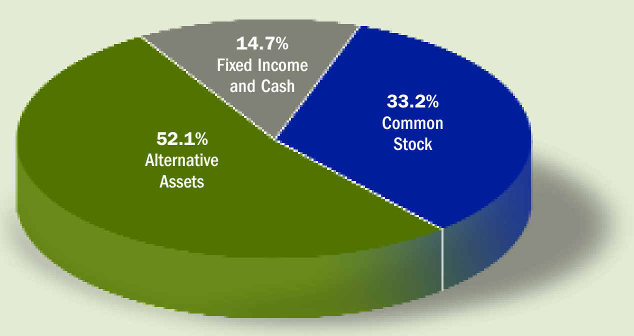
The primary source of support for the institution's activities continues to be its endowment. This reliance on institutional funding provides an important degree of independence in the research activities of the institution's scientists.

As of June 30, 2006, the endowment was valued at over $724 million and had a total annual return, net of management fees, of 16%. During the last decade, the endowment has more than doubled, growing from $338 million to more than $724 million. Carnegie's endowment has returned an annualized 11.7% over the trailing five years for the period ending June 30, 2006.

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.

Asset Class	Target	Actual
Common Stock	35.0%	33.2%
Alternative Assets	52.5%	52.1%
Fixed Income and Cash	12.5%	14.7%



The chart above shows the allocation of the institution's endowment among the asset classes it uses as of June 30, 2006.

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 pursued a long-term policy of bringing its budgeted spending rate down in a gradual fashion from 6+ % in 1992 to 5.10% in 2005-06 and to 5.00% for the coming year. Carnegie's spending policy averages the total market value of the endowment for the three most recently completed fiscal years and develops a budget that spends at a set percentage of this three-year market value. The following figure depicts actual spending as a percentage of ending market value and compares that amount with the budgeted spending rate based on the three-year average.

BUDGETED AND ACTUAL SPENDING RATES

Within Carnegie's endowment, there are a number of "Funds" that provide support either in a general way or targeted to a specific purpose. These funds reflect a portion of the generous support provided to the institution. The largest of these is the Andrew Carnegie Fund, valued at over $642 million today. This fund was begun with an original gift of $10 million. Mr. Carnegie later made additional gifts totaling another $12 million during his lifetime.

PRINCIPAL FUNDS UNDER ACTIVE INVESTMENT MANAGEMENT

(FY 2006; includes $724 million of endowment and other assets)

Andrew Carnegie	$642,177,675
Mellon Matching	15,781,373
Astronomy Funds	13,875,892
Capital Campaign	9,894,997
Anonymous	9,421,232
Anonymous Matching	9,208,751
Wood	7,938,776
Golden	6,041,542
Science Education Fund	3,534,665
Colburn	2,422,607
McClintock Fund	2,294,304
Endowed Fellowships	1,839,904
Bush Bequest	1,828,200
Starr Fellowship	1,049,848
Roberts	597,198
Lundmark	438,386
Hollaender	355,909
Forbush	195,125
Hale	173,210
Green Fellowship	169,285
Harkavy	165,235
Endowed Observatories Positions	151,020
Total	**$729,555,134**

In future years Carnegie anticipates continuing to pursue an investment policy which seeks to maximize expected returns while minimizing volatility, a spending policy that meets immediate needs while also focusing on achieving intergenerational equity, and a development approach that increases the base of institutional support.

FINANCIAL STATEMENTS

INDEPENDENT AUDITORS' REPORT

The Audit Committee of the
Carnegie Institution of Washington:

We have audited the accompanying statements of financial position of the Carnegie Institution of Washington (Carnegie) as of June 30, 2006 and 2005, and the related statements of activities and cash flows for the years then ended. These financial statements are the responsibility of Carnegie's management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with auditing standards generally accepted in the United States of America. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

In our opinion, the financial statements referred to above present fairly, in all material respects, the financial position of the Carnegie Institution of Washington as of June 30, 2006 and 2005, and its changes in net assets and its cash flows for the years then ended, in conformity with U.S. generally accepted accounting principles.

Our audits were made for the purpose of forming an opinion on the basic financial statements taken as a whole. The supplementary information included in the schedules of expenses is presented for purposes of additional analysis and is not a required part of the basic financial statements. Such information has been subjected to the auditing procedures applied in the audits of the basic financial statements and, in our opinion, is fairly presented in all material respects in relation to the basic financial statements taken as a whole.

KPMG LLP

Washington, D.C.
March 27, 2007

STATEMENTS OF FINANCIAL POSITION

June 30, 2006 and 2005

	2006	2005
Assets		
Cash and cash equivalents	$677,851	186,133
Accrued investment income	236,931	196,512
Contributions receivable, net (note 2)	6,262,208	7,459,804
Accounts receivable and other assets	13,821,588	8,673,414
Bond proceeds held by trustee (note 6)	292,688	4,920,242
Investments (notes 3 and 13)	729,555,134	641,071,595
Property and equipment, net (notes 4, 5 and 6)	163,103,621	159,218,202
Total assets	913,950,021	821,725,902
Liabilities and Net Assets		
Liabilities:		
Accounts payable and accrued expenses	$5,513,044	7,173,434
Deferred revenue (note 5)	37,305,764	34,914,748
Broker payable	—	204,718
Bonds payable (note 6)	65,194,134	64,710,315
Accrued postretirement benefits (note 8)	17,958,000	15,625,000
Total liabilities	125,970,942	122,628,215
Net assets (note 9):		
Unrestricted:		
Invested in property and equipment, net	66,712,191	66,792,849
Held for managed investment	603,409,368	524,262,300
Undesignated	32,507,942	32,446,383
Total unrestricted net assets	702,629,501	623,501,532
Temporarily restricted	30,765,782	36,086,697
Permanently restricted	54,583,796	39,509,458
Total net assets	787,979,079	699,097,687
Commitments and contingencies (notes 8, 10, 11 and 12)		
Total liabilities and net assets	**913,950,021**	**821,725,902**

See accompanying notes to financial statements.

STATEMENTS OF ACTIVITIES

Years ended June 30, 2006 and 2005

	Unrestricted	Temporarily Restricted	Permanently Restricted
Revenues and support:			
External revenue:			
Grants and contracts	$30,590,596	—	—
Contributions and gifts (note 13)	906,375	5,964,402	1,513,670
Net losses on disposals of property	(9,290)	—	—
Gain (loss) on interest rate swap agreements (note 7)	2,718,086	—	—
Other income	2,897,577	—	—
Net external revenue	37,103,344	5,964,402	1,513,670
Investment income, net (note 3)	117,798,640	5,664,924	39,430
Net assets released from restrictions (note 9)	6,007,638	(6,007,638)	—
Matching of endowment (note 9)	(2,578,635)	(10,942,603)	13,521,238
Total revenues and other support	158,330,987	(5,320,915)	15,074,338
Expenses:			
Program expenses:			
Terrestrial Magnetism	10,667,105	—	—
Observatories	21,191,344	—	—
Geophysical Laboratory	13,101,603	—	—
Embryology	10,374,852	—	—
Plant Biology	10,617,264	—	—
Global Ecology	3,801,733	—	—
Other programs	603,602	—	—
Total program expenses	70,357,503	—	—
Administrative and general expenses	8,845,515	—	—
Total expenses	79,203,018	—	—
Change in net assets	79,127,969	(5,320,915)	15,074,338
Net assets at beginning of year	623,501,532	36,086,697	39,509,458
Net assets at end of year	**$702,629,501**	**30,765,782**	**54,583,796**

See accompanying notes to financial statements.

2006	2005			
TOTAL	**Unrestricted**	**Temporarily Restricted**	**Permanently Restricted**	**TOTAL**
30,590,596	30,441,132	—	—	30,441,132
8,384,447	1,024,221	6,528,348	258,502	7,811,071
(9,290)	(15,971)	—	—	(15,971)
2,718,086	(1,630,883)	—	—	(1,630,883)
2,897,577	2,461,285	—	—	2,461,285
44,581,416	32,279,784	6,528,348	258,502	39,066,634
123,502,994	68,602,358	7,958,402	—	76,560,760
—	4,310,056	(4,310,056)	—	—
—	—	—	—	—
168,084,410	105,192,198	10,176,694	258,502	115,627,394
10,667,105	10,410,336	—	—	10,410,336
21,191,344	17,476,880	—	—	17,476,880
13,101,603	12,428,988	—	—	12,428,988
10,374,852	7,156,120	—	—	7,156,120
10,617,264	10,802,853	—	—	10,802,853
3,801,733	3,238,612	—	—	3,238,612
603,602	826,901	—	—	826,901
70,357,503	62,340,690	—	—	62,340,690
8,845,515	7,027,710	—	—	7,027,710
79,203,018	69,368,400	—	—	69,368,400
88,881,392	35,823,798	10,176,694	258,502	46,258,994
699,097,687	587,677,734	25,910,003	39,250,956	652,838,693
787,979,079	**623,501,532**	**36,086,697**	**39,509,458**	**699,097,687**

STATEMENTS OF CASH FLOWS

Years ended June 30, 2006 and 2005

	2006	2005
Cash flows from operating activities:		
Change in net assets	$88,881,392	46,258,994
Adjustments to reconcile increase in net assets to net cash used in operating activities:		
Depreciation	7,581,749	7,175,082
Net gains on investments	(112,570,866)	(68,562,395)
Contributions of stock	(1,498,816)	(1,408,922)
Losses on disposals of property	9,290	15,971
Amortization of bond issuance costs and discount	46,076	39,957
Contributions and investment income restricted for long-term investment	(2,734,850)	(3,694,970)
(Increase) decrease in assets:		
Receivables	(3,950,578)	(553,149)
Accrued investment income	(40,419)	(97,468)
Increase (decrease) in liabilities:		
Accounts payable and accrued expenses	(1,865,108)	3,262,243
Deferred revenue	2,391,016	219,730
Accrued postretirement benefits	2,333,000	1,955,000
Net cash used in operating activities	(21,418,114)	(15,389,927)
Cash flows from investing activities:		
Acquisition of property and equipment	(3,092,859)	(5,050,401)
Construction of telescope, facilities, and equipment	(8,387,529)	(16,545,615)
Proceeds from sales of property and equipment	3,930	—
Investments purchased	(178,788,118)	(541,308,692)
Proceeds from investments sold or matured	204,374,261	560,978,123
Proceeds from sales of investments by bond trustee	4,627,554	13,288,949
Net cash provided by investing activities	18,737,239	11,362,364
Cash flows from financing activities:		
Retirement of 1993 Series A Bonds	(17,500,000)	—
Proceeds from bond issuance	18,300,000	—
Bond issuance costs capitalized	(362,257)	—
Proceeds from contributions and investment income restricted for:		
Investment in endowment	40,000	300,000
Investment in property and equipment	2,694,850	3,394,970
Net cash provided by financing activities	3,172,593	3,694,970
Net increase (decrease) in cash and cash equivalents	491,718	(332,593)
Cash and cash equivalents at beginning of year	186,133	518,726
Cash and cash equivalents at end of year	**$677,851**	**186,133**
Supplementary cash flow information:		
Cash paid for interest	$2,240,950	2,170,122
Noncash activity – contributions of stock	1,498,816	1,408,922

See accompanying notes to financial statements.

NOTES TO FINANCIAL STATEMENTS

(1) Organization and Summary of Significant Accounting Policies

(a) Organization

The Carnegie Institution of Washington (Carnegie) conducts advanced research and training in the sciences. It carries out its scientific work in six research centers located throughout the United States and at an observatory in Chile. The centers are the Departments of Embryology, Plant Biology, Global Ecology, Terrestrial Magnetism, the Geophysical Laboratory, and the Observatories.

Income from investments represents approximately 73% and 66% of Carnegie's total revenues for the years ended June 30, 2006 and 2005, respectively. Carnegie's other income is primarily from gifts and federal grants and contracts.

(b) Basis of Accounting and Presentation

The financial statements are prepared on the accrual basis of accounting.

(c) Investments and Cash Equivalents

Carnegie's debt and equity investments are reported at fair value based on quoted market prices, or with respect to alternative investments, at estimated values provided by the general partners of limited partnerships or other external investment managers. These estimated values are reviewed and evaluated by Carnegie. Due to the inherent uncertainties of these estimates, these values may differ from the values that would have been reported had a ready market for such investments existed.

All investments are exposed to various risks such as interest rate, market and credit risks. Due to the level of risk associated with certain investment securities, it is at least reasonably possible that changes in the values of investment securities will occur in the near term and that such changes could materially affect the amounts reported in the statements of activities. All changes in fair value are recognized in the statements of activities.

Carnegie considers all highly liquid debt instruments purchased with remaining maturities of 90 days or less to be cash equivalents. Money market and other highly liquid instruments held by investment managers are reported as investments.

(d) Income Taxes

Carnegie has been recognized by the Internal Revenue Service as exempt from federal income tax under Section 501(c)(3) of the Internal Revenue Code (the Code) except for amounts from unrelated business income. Carnegie is also an educational institution within the meaning of Section 170(b)(1)(A)(ii) of the Code. The Internal Revenue Service has classified Carnegie as other than a private foundation, as defined in Section 509(a) of the Code.

(e) Fair Value of Financial Instruments

Financial instruments of Carnegie include cash equivalents, receivables, investments, bond proceeds held by trustee, accounts and broker payables, and bonds payable. The fair value of investments in debt and equity securities is based on quoted market prices. The fair value of investments in limited partnerships is based on information provided by the general partners as discussed in note 1(c) above.

The fair value of the 1993 Series A bonds payable is based on quoted market prices. The fair value of the 1993 Series B, 2002 revenue and 2006 refunding revenue bonds payable is estimated to be the carrying value, since these bonds bear adjustable market rates (see note 6).

Interest rate swap agreements are entered into by Carnegie to mitigate the risk of changes in interest rates associated with variable interest rate indebtedness. Carnegie applies the provisions of FASB Statement No. 133, *Accounting for Derivative Instruments and Hedging Activities*. This standard requires certain derivative financial instruments to be recorded at fair value.

The fair values of cash equivalents, receivables, bond proceeds held by trustee, and accounts and broker payables approximate their carrying values based on their short maturities.

(f) Use of Estimates

The preparation of financial statements in conformity with U.S. generally accepted accounting principles requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosure of contingent assets and liabilities at the date of the financial statements. Actual results could differ from those estimates.

(g) Property and Equipment

Carnegie capitalizes expenditures for land, buildings and leasehold improvements, telescopes, scientific and administrative equipment, and projects in progress. Routine replacement, maintenance, and repairs are charged to expense. Depreciation is computed on a straight-line basis, generally over the following estimated useful lives:

- **Buildings and telescopes** – 50 years
- **Leasehold improvements** – lesser of 25 years or the remaining term of the lease
- **Scientific and administrative equipment** – 2-10 years, based on scientific life of equipment

(h) Contributions

Contributions are classified based on the existence or absence of donor-imposed restrictions. Contributions are classified in categories of net assets as follows:

Unrestricted – includes all contributions received without donor-imposed restrictions on use or time.
Temporarily restricted – includes contributions with donor-imposed restrictions as to purpose of gift and/or time period expended.
Permanently restricted – generally includes endowment gifts in which donors stipulate that the corpus be invested in perpetuity. Only the investment income generated from endowments may be spent. Certain endowments require that a portion of the investment income be reinvested in perpetuity.

Contributions include unconditional promises to give. In instances where such promises are to be received after one year or more from the date of the gift, they are recorded at a discounted amount at an appropriate risk free rate commensurate with the expected collection period. Amortization of the discount is recorded as additional contribution revenue. Satisfaction of donor-imposed restrictions are reported as releases of restrictions in the statements of activities.

Gifts of long-lived assets, such as buildings or equipment, are considered unrestricted when placed in service. Cash gifts restricted for investment in long-lived assets are released from restriction when the asset is acquired or as costs are incurred for asset construction.

(i) Grants

Carnegie records revenues on grants from federal agencies only to the extent that reimbursable expenses are incurred. Accordingly, funds received in excess of reimbursable expenses are recorded as deferred revenue, and expenses in excess of reimbursements are recorded as accounts receivable. Reimbursement of indirect costs is based upon provisional rates which are subject to subsequent audit by Carnegie's federal cognizant agency, the National Science Foundation.

(j) Allocation of Costs

The costs of providing programs and supporting services have been summarized in the statements of activities. Accordingly, certain costs have been allocated among the programs and supporting services benefited. Fundraising expenses of $797,890 and $615,996 for the years ended June 30, 2006 and 2005, respectively, have been included in administrative and general expenses in the accompanying statements of activities.

(k) Reclassifications

Certain reclassifications have been made to the 2005 amounts to conform to the 2006 presentation.

(2) Contributions Receivable

Contributions receivable are summarized as follows at June 30, 2006:

Unconditional promises expected to be collected in:	
Less than one year	$1,574,373
One year to five years	5,357,101
	6,931,474
Less:	
Allowance for uncollectible amounts	(25,004)
Discount to present value	(644,262)
	$6,262,208

Pledges receivable as of June 30, 2006 and 2005 were discounted based on the estimated risk free rate of return on the pledge date at rates ranging from 2.54% to 6.00%. The allowance for uncollectible amounts and discount to present value were $6,000 and $533,938, respectively as of June 30, 2005.

(3) Investments

Investments at fair value consisted of the following at June 30, 2006 and 2005:

	2006	**2005**
Time deposits and money market funds	$43,584,622	55,825,078
Debt securities	69,802,874	68,048,149
Equity securities	181,100,396	160,682,208
Limited real estate partnerships	49,533,103	35,810,745
Limited partnerships	385,534,139	320,705,415
	$729,555,134	**641,071,595**

Investment income, net consisted of the following for the years ended June 30, 2006 and 2005:

	2006	**2005**
Interest and dividends	$11,907,701	9,024,867
Net realized gains	28,839,585	48,633,590
Net unrealized gains	83,731,281	19,928,805
Less investment management expenses	(975,573)	(1,026,502)
	$123,502,994	**76,560,760**

As of June 30, 2006 and 2005, the fair value for approximately $606.3 million and $527.4 million of Carnegie's investments has been estimated by the general partners or fund managers in the absence of readily ascertainable values as of that date.

(4) Property and Equipment

Property and equipment placed in service consisted of the following at June 30, 2006 and 2005:

	2006	2005
Buildings and improvements	$85,156,340	54,750,109
Scientific equipment	31,600,760	30,314,342
Telescopes	92,439,734	92,277,742
Construction in progress	5,590,511	30,630,550
Administrative equipment	2,649,493	2,594,566
Land	817,117	817,117
Art	38,105	38,105
	218,292,060	**211,422,531**
Less accumulated depreciation	(55,188,439)	(52,204,329)
	$163,103,621	**159,218,202**

Construction in progress consisted of the following at June 30, 2006 and 2005:

	2006	2005
Buildings	$169,562	26,717,890
Scientific equipment	5,420,949	3,912,660
Telescope	—	—
	$5,590,511	**30,630,550**

At June 30, 2006 and 2005, approximately $80.3 million and $82.8 million, respectively, of property and equipment, net of accumulated depreciation, was located in Las Campanas, Chile. During construction in 2006 and 2005, Carnegie capitalized interest costs of approximately $33,000 and $562,000, respectively, as construction in progress.

(5) Magellan Consortium

During the year ended June 30, 1998, Carnegie entered into an agreement (Magellan Agreement) with four universities establishing a consortium to build and operate the Magellan telescopes. The two Magellan telescopes are located on Manqui Peak, Las Campanas in Chile. The first telescope, with a cost of approximately $41.7 million, was placed in service during 2001. The other, with a cost of approximately $30.1 million, was placed in service in 2003.

The university members of the consortium, by contribution to the construction and operating costs of Magellan, acquire rights of access and oversight as described in the Magellan Agreement. Total contributions by the university members for construction, which amounted to $36.0 million, covered approximately 50% of the total construction costs. These monies were used by Carnegie to finance part of the Magellan Telescopes' construction costs. The contributions were recorded as deferred revenue and are being recognized ratably as income over the remaining estimated useful lives of the telescopes. As of June 30, 2006 and 2005, the deferred revenue totaled $31.5 million and $31.7 million, respectively.

(6) Bonds Payable

(a) 1993 California Educational Facilities Authority Revenue Bonds

On November 1, 1993, Carnegie issued $17.5 million each of 1993 Series A and 1993 Series B California Educational Facilities Authority Revenue tax-exempt bonds. Bond proceeds were used to finance the Magellan telescope project and the renovation of the facilities of the Observatories at Pasadena. Series A bonds were redeemed on March 14, 2006 for $17,500,000 plus accrued interest. The balances outstanding at June 30, 2006 and 2005, on the 1993 Series A issue totaled $0 and $17,500,000, respectively, and on the 1993 Series B issue totaled $17,500,000 and $17,500,000, respectively.

Series B bonds bear interest at variable money market rates (ranging from 2.25% to 3.64% during the year) in effect from time to time, up to a maximum of 12% over the applicable money market rate period of between 1 and 270 days and have a stated maturity of October 1, 2023. At the end of each money market rate period, 1993 Series B bondholders are required to offer the bonds for repurchase at the applicable money market rate. When repurchased, the Series B bonds are resold at the current applicable money market rate and for a new rate period.

Carnegie is not required to repay the 1993 Series B bonds until the October 1, 2023, maturity date. Sinking fund redemptions begin in 2019 in installments for 1993 Series B as follows.

Due October 1	
2019	$3,100,000
2020	3,400,000
2021	3,600,000
2022	3,600,000
2023	3,800,000

The fair value of 1993 Series B bonds payable at June 30, 2006 and 2005 is estimated to approximate carrying value as the mandatory tender dates on which the bonds are repriced are generally within three months of year end. The fair value of the 1993 Series A bonds payable at June 30, 2005, based on quoted market prices was estimated at $20.8 million.

Standby credit facilities have been established with SunTrust Bank in the aggregate amount of $17,500,000 for the period ending March 31, 2007. Carnegie pays 0.15% per annum on the amount of the available commitment, payable quarterly in arrears. SunTrust Bank has the option to extend the agreement, but Carnegie is not required to maintain a liquidity facility for any bonds. The standby credit facility has not been used as of June 30, 2006.

(b) 2002 Maryland Health and Higher Education Facilities Authority Revenue Bond

On October 23, 2002, the Maryland Health and Higher Education Facilities Authority (MHHEFA) issued $30 million of its Revenue Bonds on behalf of Carnegie. Bond proceeds are being used to construct and equip a new facility for Carnegie's Department of Embryology on the Johns Hopkins Homewood Campus in Baltimore, Maryland. Construction began in April 2003, and the facility was occupied in September 2005.

The balance outstanding at June 30, 2006 and 2005 on the Carnegie 2002 Series totaled $29.8 million and $29.7 million, respectively. The balance outstanding is net of unamortized bond issue costs. Bond proceeds held by the trustee and unexpended at June 30, 2006 and 2005 totaled $0 and $4.9 million, respectively.

The bonds were issued in the weekly mode and bear interest at a variable rate determined by the remarketing agent, Lehman Brothers. The rates fluctuated between 2.03% and 3.97% during the year ended June 30, 2006 (see note 7). The rate at June 30, 2006 was 3.95%. Rates on remarketed bonds are selected in such a manner that the selling price will closely approximate the face value, but under no circumstances will the rate exceed 12% per annum. Interest is payable on the first business day of each month. Bonds in the weekly mode are subject to redemption at the request of Carnegie on any interest payment date. Bonds in weekly mode can be changed to daily, commercial paper, term rate or fixed rate mode at the request of Carnegie. Bonds are subject to mandatory tender for purchase prior to any change in the interest rate mode.

Scheduled maturities and sinking fund requirements are as follows:

Due October 1	
2033	$6,000,000
2034	6,000,000
2035	6,000,000
2036	6,000,000
2037	6,000,000
	$30,000,000

Standby credit facilities have been established with SunTrust Bank in the aggregate amount of $30,000,000 as of June 30, 2003, for a period of 364 days. Carnegie pays 0.15% per annum on the amount of the available commitment, payable quarterly in arrears. SunTrust Bank has extended the agreement through March 31, 2007, but Carnegie is not required to maintain a liquidity facility for any bonds. The standby credit facility has not been used as of June 30, 2006.

(c) 2006 California Educational Facilities Authority Refunding Revenue Bonds

On February 9, 2006 Carnegie issued 2006 Series A California Educational Facilities Authority Refunding Revenue tax-exempt bonds totaling $18,300,000. Bond proceeds were used to refund all outstanding 1993 Series A California Educational Facilities Authority Revenue tax-exempt bonds that were used to finance the Magellan telescope project and the renovation of the facilities of the Observatories at Pasadena and to pay certain costs incurred in connection with the issuance of the bonds.

The balance outstanding, net of unamortized bond issue costs and bond discount, at June 30, 2006 is $17,943,862. Bond proceeds held by the trustee and unexpended at June 30, 2006 totaled $121,904.

The bonds were issued in the weekly mode and bear interest at a variable rate determined by the remarketing agent, Lehman Brothers. The rates fluctuated between 3.00% and 3.93% during the year ended June 30, 2006 (see note 7). The rate at June 30, 2006 was 3.92%. Rates on remarketed bonds are selected in such a manner that the selling price will closely approximate the face value, but under no circumstances will the rate exceed 12% per annum. Interest is payable on the first business day of each month and upon change in interest rate mode. Bonds in the weekly mode are subject to redemption at the request of Carnegie on any interest payment date. Bonds in weekly mode can be changed to daily, commercial paper, term rate or fixed rate mode at the request of Carnegie. Bonds are subject to mandatory tender for purchase prior to any change in the interest rate mode.

Carnegie is not required to repay the 2006 Series A bonds until the October 1, 2040 maturity date. Standby credit facilities have been established with SunTrust Bank in the aggregate amount of $18,300,000 for the period ending March 31, 2007. Carnegie pays 0.15% per annum on the amount of the available commitment, payable quarterly in arrears. SunTrust Bank has the option to extend the agreement, but Carnegie is not required to maintain a liquidity facility for any bonds. The standby credit facility has not been used as of June 30, 2006.

(7) Interest Rate Swap Agreements

(a) 2002 Maryland Health and Higher Education Facilities Authority Revenue Bonds

Carnegie entered into a swap agreement with an effective date of October 23, 2002. This swap agreement relates to $15 million face amount of its Series 2002 Maryland Health and Higher Education Facilities Authority Revenue Bonds (see note 6). The agreement provides for Lehman Brothers Special Financing Inc. to receive 3.717% in interest on a notional amount of $15 million and to pay interest at a floating rate of 68% of the three-month LIBOR rate, reducing on the dates and in the amounts as follows:

10/01/2033	$3,000,000
10/01/2034	3,000,000
10/01/2035	3,000,000
10/01/2036	3,000,000

The interest rate swap agreement described above is a derivative instrument that is required to be recorded at fair value. The estimated fair value at year end was an asset of $418,647 in 2006 and a liability of $1,456,776 in 2005. These amounts are included in accounts receivable and accounts payable and accrued expenses, respectively, on the accompanying statements of financial position. The change in fair value for the years ended June 30, 2006 and 2005 was a gain of $1,875,423 and a loss of $1,630,883, respectively, and is reported as other income or loss.

(b) 2006 Series A California Educational Facilities Authority Refunding Revenue Bonds

Carnegie entered into a swap agreement with an effective date of February 15, 2006. This swap agreement relates to $18.3 million face amount of its 2006 Series A California Educational Facilities Authority Refunding Revenue tax-exempt bonds (see note 6). The agreement provides for Lehman Brothers Special Financing Inc. to receive 3.603% in interest on a notional amount of $18.3 million and to pay interest at a floating rate of 68% of the three-month LIBOR rate.

The interest rate swap agreement described above is a derivative instrument that is required to be recorded at fair value. The estimated fair value at year end was an asset of $842,663 in 2006. This amount is included in accounts receivable on the accompanying statements of financial position. The change in fair value for the year ended June 30, 2006 was a gain of $842,663 and is reported as other income or loss.

(8) Employee Benefit Plans

(a) Retirement Plan

Carnegie has a noncontributory, defined contribution, money-purchase retirement plan in which all U.S. personnel are eligible to participate. After one year of participation, an individual's benefits are fully vested. The Plan has been funded through individually owned annuities issued by Teachers' Insurance and Annuity Association (TIAA) and College Retirement Equities Fund (CREF). Contributions made by Carnegie totaled approximately $3.3 million and $3.1 million for the years ended June 30, 2006 and 2005, respectively.

(b) Postretirement Benefits Plan

Carnegie provides postretirement medical benefits to all employees who retire after age 55 and have at least 10 years of service. Cash payments made by Carnegie for these benefits totaled approximately $452,000 and $623,000 for the years ended June 30, 2006 and 2005, respectively.

The expense for postretirement benefits for the years ended June 30, 2006 and 2005 consists of the following:

	2006	2005
Service cost – benefits earned during the year	$1,512,000	1,151,000
Interest cost on projected benefit obligation	1,078,000	1,184,000
Amortization of gain	195,000	243,000
Postretirement benefit cost	**$2,785,000**	**2,578,000**

The 2006 postretirement benefits expense was approximately $2,333,000 more than the cash expense of $452,000 and the 2005 postretirement benefits expense was approximately $1,955,000 more than the cash expense of $623,000. The postretirement benefits expense was allocated among program and supporting services expenses in the accompanying statements of activities.

The reconciliation of the Plan's funded status to amounts recognized in the financial statements at June 30, 2006 and 2005 follows:

	2006	2005
Change in benefit obligation:		
Benefit obligation at beginning of year	$20,807,000	19,200,000
Service cost	1,512,000	1,151,000
Interest cost	1,078,000	1,184,000
Plan amendments	(293,000)	—
Actuarial loss	(3,941,000)	(105,000)
Benefits paid	(452,000)	(623,000)
Benefit obligation at end of year	**18,711,000**	**20,807,000**
Change in plan assets:		
Fair value of plan assets at beginning of year	—	—
Actual return on plan assets	—	—
Contribution to plan	452,000	623,000
Benefits paid	(452,000)	(623,000)
Fair value of plan assets at end of year	—	—
Funded status	(18,711,000)	(20,807,000)
Unrecognized net actuarial loss (gain)	1,046,000	5,182,000
Unrecognized prior service cost	(293,000)	—
Accrued benefit cost	**$(17,958,000)**	**(15,625,000)**

The present value of the benefit obligation as of June 30, 2006 was determined using an assumed discount rate of 6.25%. The present value of the benefit obligation as of June 30, 2005 was determined using an assumed discount rate of 5.25%. Carnegie's policy is to fund postretirement benefits as claims and administrative fees are paid.

For measurement purposes, a 10% annual rate of increase in medical claims was assumed for 2006; the rate of increase was assumed to decrease over the next three years at 1% per year, then in increments of 0.50% for the next five years, eventually reaching 5.5% in 2013. The healthcare cost trend rate assumption has a significant effect on the amounts reported. An one-percentage point change in assumed annual healthcare cost trend rate would have the following effects:

	One-percentage point increase	One-percentage point decrease
Effect on total of service and interest cost components	$899,000	(675,000)
Effect on postretirement benefit obligation	3,275,000	(2,592,000)

The measurement date used to determine postretirement benefit obligations is July 1.

Carnegie expects to contribute approximately $558,000 to its postretirement benefit plan during the year ended June 30, 2006.

The following benefit payments (net of retiree contributions), which reflect expected future service, are expected to be paid in future years ending June 30:

2007	$558,000
2008	658,000
2009	741,000
2010	798,000
2011-2014	5,153,000

On December 8, 2003, the President signed into law the Medicare Prescription Drug Improvement and Modernization Act of 2003 (the Act). Under the Medicare Prescription Drug Program, as proposed under the Act, groups who offer retiree prescription drug coverage at least actuarially equivalent to Medicare Plan D are eligible for a subsidy. In 2004, the Financial Accounting Standards Board issued SFAS No. 106-2, Accounting and Disclosure Requirements Related to the Medicare Prescription Drug, Improvement and Modernization Act of 2003, which is effective for fiscal years beginning after June 15, 2004, with early adoption encouraged.

Carnegie has adopted this standard in 2005. Based on the Carnegie Plan amendments effective July 1, 2005, the prescription drug benefits offered by Carnegie were determined to not be actuarially equivalent to Medicare Plan D, and the effects of the Act, excluding the subsidy, do not have a significant impact on the per capita claims cost.

(9) Net Assets

(a) Temporarily Restricted Net Assets

Temporarily restricted net assets were available to support the following donor-restricted purposes at June 30, 2006 and 2005:

	2006	2005
Specific research programs	$16,605,270	13,782,554
Equipment acquisition and construction	12,813,990	20,102,408
Passage of time	1,346,522	2,201,735
	$30,765,782	**36,086,697**

(b) Permanently Restricted Net Assets

Permanently restricted net assets consisted of endowed gifts, the income from which is available to support the following donor-restricted purposes at June 30, 2006 and 2005:

	2006	2005
Specific research programs	$14,819,077	14,799,327
Operation of Maxine Singer Building	15,000,000	—
Equipment acquisition and construction	2,764,719	2,710,13
General support (Carnegie endowment)	22,000,000	22,000,000
	$54,583,796	**39,509,458**

(c) Net Assets Released from Restrictions and Matching of Endowment

During 2006 and 2005, Carnegie met donor-imposed requirements on certain gifts and, therefore, released temporarily restricted net assets as follows:

	2006	2005
Specific research programs	$4,386,403	2,126,126
Equipment acquisition and construction	1,620,235	2,139,930
Passage of time	1,000	44,000
	$6,007,638	**4,310,056**

During 2006, Carnegie allocated $2,578,635 of unrestricted net assets and $10,942,603 of temporarily restricted net assets to establish an endowment for the Maxine Singer Building to match a donor's contribution. This amount is included as operation of Maxine Singer Building in permanently restricted net assets and as matching of endowment on the accompanying statements of activities.

(10) Commitments

Carnegie entered into a contract with the University of Arizona for the construction of a secondary mirror and support system for the second telescope in the Magellan project. The original amount of the contract was approximately $590,000; $318,000 remained outstanding on June 30, 2006.

Carnegie has outstanding commitments to invest approximately $117.7 million in limited partnerships at June 30, 2006.

(11) Lease Arrangements

Carnegie leases a portion of the land it owns in Las Campanas, Chile to other organizations. These organizations have built and operate telescopes on the land. Most of the lease arrangements are not specific and some are at no cost to the other organizations. The value of the no-cost leases could not be determined and is not considered significant and, accordingly, contributions have not been recorded in the financial statements.

Carnegie also leases a portion of one of its laboratories to another organization for an indefinite term. Rents to be received under the agreement are approximately $680,000 annually, adjusted for CPI increases.

Carnegie leases land and buildings for various research departments. The monetary terms of the leases are considerably below fair value; however, these terms were developed considering other nonmonetary transactions between Carnegie and the lessors. The substance of the transactions indicates arms-length terms between Carnegie and the lessors.

(12) Contingencies

Costs charged to the federal government under cost-reimbursement grants and contracts are subject to government audit. Therefore, all such costs are subject to adjustment. Management believes that adjustments, if any, would not have a significant effect on the financial statements.

(13) Related Party Transactions

Carnegie recorded contributions from its trustees, officers and directors of $2,217,102 and $2,419,419, for the years ended June 30, 2006 and 2005, respectively.

A trustee of Carnegie is also the Chairman of an investment entity with which Carnegie has invested $103 million and $64.3 million in four of its investment funds, as of June 30, 2006 and 2005, respectively.

SCHEDULES OF EXPENSES

Years ended June 30, 2006 and 2005

	2006		
	Carnegie Funds	**Federal and Private Grants**	**Total Expenses**
Personnel costs:			
Salaries	$16,351,247	5,846,475	22,197,722
Fringe benefits and payroll taxes	10,762,045	2,743,411	13,505,456
Total personnel costs	27,113,292	8,589,886	35,703,178
Fellowship grants and awards	2,115,590	929,264	3,044,854
Depreciation	7,581,749	—	7,581,749
General Expenses:			
Educational and research supplies	7,999,243	2,065,686	10,064,929
Building maintenance and operation	3,186,777	176,889	3,363,666
Travel and meetings	1,298,785	807,656	2,106,441
Publications	23,256	59,442	82,698
Shop	133,911	9,646	143,557
Telephone	197,719	3,752	201,471
Books and subscriptions	259,984	—	259,984
Administrative and general	8,923,535	375,871	9,299,406
Facilities construction	2,422,558	—	2,422,558
Interest	2,354,287	—	2,354,287
Subcontracts	88,207	4,471,903	4,560,110
Shipping and postage	162,132	14,875	177,007
Insurance, taxes, and professional fees	2,712,539	168,288	2,880,827
Equipment	3,927,191	1,390,001	5,317,192
Fundraising expense	797,890	—	797,890
Total general expenses	34,488,014	9,544,009	44,032,023
Total direct costs	71,298,645	19,063,159	90,361,804
Indirect costs:			
Grants and contracts	(11,400,788)	11,400,788	—
Total costs	59,897,857	30,463,947	90,361,804
Capitalized scientific equipment and facilities	(10,029,303)	(1,129,483)	(11,158,786)
Total expenses	**$49,868,554**	**29,334,464**	**79,203,018**

See accompanying independent auditors' report.

2005		
Carnegie Funds	Federal and Private Grants	Total Expenses
15,223,153	5,651,882	20,875,035
10,449,769	2,590,285	13,040,054
25,672,922	8,242,167	33,915,089
2,382,882	861,146	3,244,028
7,175,082	—	7,175,082
2,407,908	2,325,483	4,733,391
2,735,676	199,704	2,935,380
1,087,848	910,420	1,998,268
33,481	50,210	83,691
117,856	8,743	126,599
195,912	3,211	199,123
258,211	—	258,211
2,176,597	3,853,590	6,030,187
14,211,686	—	14,211,686
1,859,438	—	1,859,438
152,192	4,331,717	4,483,909
108,677	15,406	124,083
2,198,587	236,356	2,434,943
3,825,763	2,008,182	5,833,945
615,996	—	615,996
31,985,828	13,943,022	45,928,850
67,216,714	23,046,335	90,263,049
(7,400,796)	7,400,796	—
59,815,918	30,447,131	90,263,049
(19,061,636)	(1,833,013)	(20,894,649)
40,754,282	**28,614,118**	**69,368,400**

PERSONNEL *July 1, 2005-June 30, 2006*

Carnegie Administration

Sharon Bassin, *Assistant to the President/ Assistant Secretary to the Board*
Gloria Brienza, *Budget and Management Analysis Manager*
Don Brooks, *Building Maintenance Specialist*
Marjorie Burger, *Financial Accountant*
Cady Canapp, *Human Resources and Insurance Manager*
Ellen Carpenter, *Public Events and Publications Coordinator*
Heather Davis, *Financial Accountant*[1]
Linda Feinberg, *Manager of External Affairs*
Susanne Garvey, *Director of External Affairs*
Claire Hardy, *Database and Communications Coordinator*[2]
Darla Keefer, *Special Assistant for Administration and Building Operations*
Ann Keyes, *Payroll Coordinator*
George Gary Kowalczyk, *Director of Administration and Finance*[3]
Jeffrey Lightfield, *Deputy to the Financial Manager*[4]
John Lively, *Director of Administration and Finance*[5]
Rhoda Mathias, *Secretary to the President*
Tina McDowell, *Editor and Publications Officer*
Benjamin McWhorter, *Database Support*[6]
Richard Meserve, *President*
June Napoco-Soriente, *Financial Accountant*[7]
Trong Nguyen, *Financial Accountant*
Michael Pimenov, *Endowment Manager*
Arnold Pryor, *Facilities Coordinator*
Gotthard Sághi-Szabó, *Chief Information Officer*
Christine Smith, *Chief Advancement Officer*[8]
John Strom, *Web Manager*
Kris Sundback, *Financial Manager*
Mira Thompson, *Advancement Assistant*[9]
Vickie Tucker, *Administrative Coordinator/ Accounts Payable*
Yulonda White, *Human Resources and Insurance Records Coordinator*
Jacqueline Williams, *Assistant to Manager, Human Resources and Insurance*
Matthew Wright, *Science Writer and Publications Coordinator*[10]

[1]From May 8, 2006
[2]To June 2, 2006
[3]From February 21, 2006
[4]To February 1, 2006
[5]To January 31, 2006
[6]From January 3, 2006
[7]From April 10, 2006
[8]From January 23, 2006
[9]From June 19, 2006
[10]From September 26, 2005

Carnegie Academy for Science Education

Sarah Bax, *Mentor Teacher*[1]
John Bucchanan, *Mentor Teacher*[2]
Derek Butts, *First Light Assistant*
Asonja Dorsey, *Mentor Teacher*[1,2]
VanNessa Duckett, *Mentor Teacher*[1,2]
Audrey Edmonds, *Intern*[1,2]
Julie Edmonds, *Codirector*
Ricky Gabray, *Intern*[1,2]
Joseph Geglia, *Intern*[1,2]
Anne Hemphill, *Mentor Teachers*[1,2]
Toby Horn, *Codirector*
Adedoyin Kalejaiye, *Intern*[1]
Loretta Kelly, *Mentor Teacher*[1,2]
Lynn Lahti-Hommeyer, *Mentor Teacher*[1]
Rebecca Lippy, *Intern*[1]
Fran McCrackin, *Mentor Teacher*[1,2]
Thomas Nassif, *Mentor Teacher*[1,2]
Maxine Singer, *Senior Scientific Advisor*
Shahza Somerville, *Summer Biotech Instructor*[2]
John Tatum, *Mentor Teacher*[1]
Annie Thompson, *Mentor Teacher*[1,2]
Latisha Whitley, *Intern*[1,2]
Haimanot Worku, *Intern*[1]

[1]Summer Institute 2005
[2]Summer Institute 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

STAFF ASSOCIATES

Jeffrey Han[1]
David MacPherson[2]
Terence Murphy[3]
Alex Schreiber
Jim Wilhelm
Judy Yanowitz

POSTDOCTORAL FELLOWS AND ASSOCIATES

Matt Berezuk, *Carnegie Fellow*[4]
Michael Buszczak, *ACS Fellowship*
Liquan Cai, *NIH Grant (Brown)*
Anna Chan, *Howard Hughes Medical Institute Research Associate*[5]
Rachel Cox, *Howard Hughes Medical Institute Research Specialist*
Biswajit Das, *Mathers Charitable Foundation (Brown)*[6]
Eva DeCotto, *Howard Hughes Medical Institute Research Associate*[6]
Hongjuan Gao, *Carnegie Fellow*[4]
Mary Goll, *Carnegie Fellow*[7]
Daniel Gorelick, *Postdoctoral Fellow, Carnegie Fellow (Halpern)*
Vinny Guacci, *Howard Hughes Medical Institute Research Specialist*[8]
Kotaro Hama, *Carnegie Fellow*[9]
Catherine Huang, *ACS Fellowship*
Yung-Shu Kuan, *Carnegie Fellow*
Bob Levis, *Special Investigator, NIH Grant (Spradling with University of California, Berkeley, subcontract)*
Liang Liang, *Howard Hughes Medical Institute Research Associate*
Ji-Long Liu, *Carnegie Fellow*
Zhonghua Liu, *Howard Hughes Medical Institute Research Associate*[4]

DEPARTMENT OF EMBRYOLOGY First row (left to right): Marnie Halpern, Elcin Unal, Rejeanne Juste, Ella Jackson, Ellen Cammon, Glenese Johnson, Rosa Miyares, Karina Conkrite, Zehra Nizami, Jaya Kuchibhotla. Second row (left to right): Earl Potts, Joe Gall, David MacPherson, Mary Goll, Hongjuan Gao, Queenie Vong, Anna Chan, Stephanie Owen, Anastasia Krasnoperova, Zheng-an Wu, Yan Tan, Ji-Long Liu, Alex Bortvin. Third row (left to right): Wendy McKoy, Jeff Han, Michelle Macurak, Tara Hardiman, Sarah Clatterbuck, Katie Huang, Anna Allen, Tina Tootle, Robert DeRose, Liquan Cai, Kiran Santhakumar, Robyn Goodman, Eugenia Dikovskaia, Margaret Hoang, Courtney Akitake, Dolly Chin. Fourth row (left to right): Doug Koshland, Vinny Guacci, Carol Davenport, Lori Orosco, Lucy Morris, Allison Pinder, Ben Ohlstein, Rafael Villagaray, Ben Goodman, Shusheng Wang, Dianne Williams, Chen-ming Fan, Safia Malki, Christine Pratt. Fifth row (left to right): Andrew Skora, Steve Farber, Mahmud Siddiqi, Andrew Eifert, Melinda Campbell, Dan Gorelick, Alex Schreiber, Allan Spradling, Robert Levis, Jim Wilhelm. Sixth row (left to right): Nicole Gabriel, Yung-shu Kuan, Keeyana Singleton, Jill Heidinger, Judith Yanowitz, Michael Buszczak. Seventh row (left to right): Cynthia Wagner, Dean Calahan, Donald Brown, Cheng Xu, Sandeep Mukhi, Tom McDonaugh.

Jinzhe Mao, *Mathers Charitable Foundation (Brown), NIH Grant (Brown)*[10]
Lucy Morris, *Howard Hughes Medical Institute Research Associate*[4]
Todd Nystul, *Life Sciences Research Foundation Fellow*
Ben Ohlstein, *Howard Hughes Medical Institute Research Associate*
Joanna Paterson, *Carnegie Fellow*[4]
Kiran Santhakumar, *NIH Grant (Halpern)*
Zi-Qing Sun, *Carnegie Fellow*
Tina Tootle, *Howard Hughes Medical Institute Research Associate*
Ming-Ying Tsai, *Howard Hughes Medical Institute Research Associate*
Queenie Vong, *Howard Hughes Medical Institute Research Associate*
Cynthia Wagner, *Special Investigator, Carnegie Fellow*
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*

PREDOCTORAL FELLOWS AND ASSOCIATES

Courtney Akitake (formerly Hoshibata), *The Johns Hopkins University*
Anna Allen (formerly Krueger), *The Johns Hopkins University*
Dean Calahan, *The Johns Hopkins University*
Julio Castaneda, *The Johns Hopkins University*[5]
Wilbur Channels, *The Johns Hopkins University*[11]
Sara Clatterbuck, *The Johns Hopkins University*
Robert DeRose, *The Johns Hopkins University*
Jovita Diaz, *The Johns Hopkins University*[12]
Daniel Ducat, *The Johns Hopkins University*
Ben Goodman, *The Johns Hopkins University*[13]
Robyn Goodman, *The Johns Hopkins University*
Jill Heidinger, *The Johns Hopkins University*
Margaret Hoang, *The Johns Hopkins University*
Christoph Lepper, *The Johns Hopkins University*
Daniel Lighthouse, *The Johns Hopkins University*
Peter Lopez, *The Johns Hopkins University*
David Martinelli, *The Johns Hopkins University*
Mark Milutinovich, *The Johns Hopkins University*[14]
Tim Mulligan, *The Johns Hopkins University*
Zehra Nizami, *The Johns Hopkins University*[15]
Lori Orosco, *The Johns Hopkins University*
Andrew Skora, *The Johns Hopkins University*
Christopher (Kai) Sung, *The Johns Hopkins University*[3]
Elcin Unal, *The Johns Hopkins University*
Rachel Webster, *The Johns Hopkins University*[11]

SUPPORTING STAFF

Sarah Adams, *P/T Fish Feeder*[1]
Or Amit, *Technician*[16]
Jen Anderson, *Technician*
Christina Bonsanti, *P/T Fish Feeder*[17]
Ellen Cammon, *Howard Hughes Medical Institute Research Technician I*
Patricia Cammon, *Howard Hughes Medical Institute Laboratory Helper*
Melinda Campbell, *Technician*[18]
Paul Capestany, *Technician*[5]
Dolly Chin, *Administrative Assistant*[19]
Karina Conkrite, *Technician*[20]
Carol Davenport, *Howard Hughes Medical Institute Research Technician III*
Eugenia Dikovskaia, *Animal Facility Manager*
Christopher Edwards, *Technician*[21]
Pat Englar, *Director's Administrative Assistant*[11]
Lea Fortuno, *Animal Care Technician*
Nicole Gabriel, *Animal Care Technician*

Oliver Gibbon, *P/T Lab Assistant*[22]
Aja Green, *Technician*[23]
Warren Hall, *Animal Care Technician*
Tara Hardiman, *Technician*
Javi Hartenstine, *P/T Fish Feeder*[1]
Eileen Hogan, *Howard Hughes Medical Institute Research Technician III*[24]
Ella Jackson, *Howard Hughes Medical Institute Laboratory Helper*
Fred Jackson, *P/T Animal Care Technician*
Connie Jewell, *Systems Administrator*
Glenese Johnson, *Laboratory Helper*
Rejeanne Juste, *Technician*
Susan Kern, *Business Manager*
Andrew Kim, *Technician*[17]
Anastasia Krasnoperova, *Lab Assistant*
Bill Kupiec, *Information Systems Manager*
Megan Kutzer, *Technician*
Melissa Lee, *P/T Lab Helper*
Jaclyn Lim, *Lab Assistant*[1]
Michelle Macurak, *Technician*
Ona Martin, *Howard Hughes Medical Institute Research Technician III*
Tom McDonaugh, *Facilities Manager*
Wendy McKoy, *Administrative Assistant*[1]
Vashti Miles, *Technician*[25]
Christine Murphy, *Senior Technician*[26]
Stephanie Owen, *Technician*
Shelley Paterno, *Howard Hughes Medical Institute Research Technician II*
Allison Pinder, *Howard Hughes Medical Institute Research Technician III*
Earl Potts, *Custodian*
Christine Pratt, *Howard Hughes Medical Institute Administrative Assistant II*
Michael Sepanski, *Electron Microscopy Technician*
Mahmud Siddiqi, *Research Specialist*
Loretta Steffy, *Accounting Assistant*
Allen Strause, *Machinist*
Yan Tan, *Technician*
Rafael Villagaray, *Computer Technician*
Xin Wang, *P/T Laboratory Help*[1]
John Watt, *Librarian*[11]
Christopher Weier, *P/T Fish Feeder*
Mike Welch, *Technician*
Allisandra Wen, *P/T Fish Feeder*
Michael Willey, *Animal Care Technician*[27]
Dianne Williams, *Howard Hughes Medical Institute Research Technician III*
Anialac Zavala, *P/T Fish Feeder*[1]

VISITING INVESTIGATORS AND COLLABORATORS

Kiyokazu Agata, *Okayama University, Japan*
David Baillie, *Simon Fraser University, British Columbia, Canada*
Robert Baker, *Department of Neuroscience, New York University*
James Beck, *Department of Neuroscience, New York University*
Hugo Bellen, *Baylor College of Medicine*
Carolyn Bergstrom, *Bamfield Marine Science Centre, British Columbia, Canada*
Charles Brenner, *Department of Genetics and Biochemistry, Dartmouth Medical School*
Dana Carroll, *Department of Biochemistry, University of Utah*
Francesc Cebria, *Departament de Genètica, Universitat de Barcelona*
Rosalind Coleman, *Department of Nutrition, University of North Carolina*
Michael Dean, *Laboratory of Genomic Diversity, NCI-Frederick, MD*
Maitreya Dunham, *Carl Icahn Laboratory, Princeton University*
Steven Ekker, *Department of Genetics, Cell Biology and Development, University of Minnesota Medical School*
David Ginty, *Professor, HHMI, Department of Neuroscience, The Johns Hopkins University School of Medicine*
Michael Granato, *Department of Cell and Developmental Biology, University of Pennsylvania Medical School*
Matthias Hammerschmidt, *Max Planck Institute of Immunobiology, Freiburg, Germany*
Lizbeth Hedstrom, *Department of Biochemistry, Brandeis University*
Nancy Hopkins, *Department of Biology, Massachusetts Institute of Technology*
Roger Hoskins, *Lawrence Berkeley National Laboratory*
Chiyoko Kobayashi, *Okayama University, Japan*
Steven Leach, *Departments of Surgery and Oncology, The Johns Hopkins University School of Medicine*
Christopher Miller, *Department of Biochemistry, Brandeis University*
Cecilia Moens, *Fred Hutchinson Cancer Research Center*
Mari Moren, *National Institute of Nutrition and Seafood Research, Bergen, Norway*
Karen Oogema, *European Molecular Biology Laboratory, Heidelberg, Germany*
Michael Pack, *Department of Medicine and Cell and Developmental Biology, University of Pennsylvania School of Medicine*
Erez Raz, *Department of Germ Cell Development, Max Planck Institute for Biophysical Chemistry, Germany*
Rafael Romero, *Departament de Genètica, Universitat de Barcelona*
Christopher Rose, *Department of Biology, James Madison University*
Gerald M. Rubin, *University of California, Berkeley*
Bernard Thisse, *Institut de Génétique et de Biologie Moléculaire et Cellulaire, CNRS INSERM ULP*
Christine Thisse, *Institut de Génétique et de Biologie Moléculaire et Cellulaire, CNRS INSERM ULP*
Milena Vuica, *Department of Pathology, The Johns Hopkins University School of Medicine*
Wade Watanabe, *University of North Carolina at Wilmington*

[1]From January 1, 2006
[2]From September 1, 2005
[3]To September 16, 2005
[4]From February 1, 2006
[5]From July 1, 2005
[6]To October 30, 2005
[7]From June 6, 2006
[8]From March 1, 2006
[9]From April 1, 2006
[10]To March 20, 2006
[11]To June 30, 2006
[12]To February 1, 2006
[13]From May 21, 2006
[14]To February 21, 2006
[15]From June 1, 2006
[16]From May 11, 2006
[17]To April 10, 2006
[18]From April 26, 2006
[19]From June 26, 2006
[20]From October 1, 2005
[21]To March 13, 2006
[22]To August 10, 2005
[23]To April 30, 2006
[24]To January 31, 2006
[25]From September 1, 2005
[26]To June 30, 2006
[27]To March 30, 2006

Geophysical Laboratory

RESEARCH STAFF MEMBERS

George D. Cody
Ronald E. Cohen
Yingwei Fei
Marilyn L. Fogel
Alexander Goncharov[1]
Robert M. Hazen
Russell J. Hemley
Wesley T. Huntress, Jr., *Director*
T. Neil Irvine, *Emeritus*
Ho-kwang Mao
Bjørn O. Mysen
Douglas Rumble III
Andrew Steele
Viktor Struzhkin

STAFF ASSOCIATES

Przemyslaw Dera
Burkhard Militzer
James Scott

SENIOR RESEARCH FELLOW

Dudley R. Herschbach, *Cecil and Ida Green Senior Fellow*

RESEARCH SCIENTISTS

Peter M. Bell, *Adjunct Senior Research Scientist*
Nabil Z. Boctor, *NASA, NASA Astrobiology Institute*
Eugene A. Gregoryanz, *Carnegie, CDAC*[2]
Jung-Fu Lin, *CDAC*
Maddury S. Somayazulu, *CDAC*[3]
Chang-Sheng Zha, *CDAC*[4]

SUMMER EDUCATION COORDINATOR AND RESEARCH SCIENTIST

Stephen A. Gramsch, *CDAC Manager*

GEOPHYSICAL LABORATORY Front row (left to right): Margie Imlay, Ho-kwang Mao, Douglas Rumble, III, George Cody, Bjørn Mysen, Russell Hemley, Wesley Huntress, Jr., Marilyn Fogel, Yingwei Fei, Robert Hazen, Ronald Cohen, Alexander Goncharov, Viktor Struzhkin. Second row (left to right): Andrey Bekker, Kenneth Esler, Maddury Somayazulu, Chang-Sheng Zha, Pablo Esparza, Susana Mysen, Yeny Marili, Morgan Phillips, Pedro Roa, Adelio Contreras, Jennifer Ciezak, Liwei Deng, Li Zhang, Shuhei Ono, Giles Maule, Shaun Hardy, Gotthard Sághi-Szabó, Nicholas Platt. Third row (left to right): visitor, Trong Nguyen, Joseph Lai, Felix Krasnidki, Gary Bors, Alexander Smirnov, Chris Hadidiacos, Stephen Gramsch, Pierre Beck, Dean Presnall, Tim Jenkins, Jeff Lightfield, Angèle Ricolleau, Merri Wolf, Stephen Hodge, Matthew Schrenk, Alexander Kollias. Back row (left to right): Dominic Papineau, Yufei Meng, Chih-Shiue Yan, Jinfu Shu, Fabian Moscoso, Roy Dingus, Maceo Bacote, Steve Coley, Hikaru Yabuta, Bobbie Brown, Xianwei Sha, Jan Vorberger, James Cleaves.

HIGH PRESSURE COLLABORATIVE ACCESS TEAM (HPCAT), ARGONNE NATIONAL LABORATORY, CHICAGO; AND BROOKHAVEN NATIONAL LABORATORY, UPTON, NY

Arunkumar S. Bommannavar, *Beamline Control Scientist*
Paul Chow, *Beamline Scientist*
Yang Ding, *Research Scientist*
Quanzhong Guo, *Beamline Scientist*[5]
Daniel Häusermann, *Project Manager*[6]
Jingzhu Hu, *Beamline Scientist*[7]
Michael Y. Hu, *Beamline Scientist*
Hanns-Peter Liermann, *Beamline Scientist*
Jing Liu, *GL and HPCAT Research Scholar*[40]
Haozhe Liu, *Research Scientist*
Zhen-Xian Liu, *Beamline Scientist*
Ho-kwang Mao, *Director*
Yue Meng, *Beamline Scientist*
Veronica O'Connor, *Office Manager*
Eric Rod, *Beamline Technician*
Guoyin Shen, *Project Manager*[8]
Jinfu Shu, *Research Technician*
Stanislav Sinogeikin, *Beamline Scientist*[9]
Maddury S. Somayazulu, *Beamline Scientist*[10]
Jian Xu, *Research Scientist*
Wenge Yang, *Beamline Scientist*[11]

POSTDOCTORAL FELLOWS AND POSTDOCTORAL RESEARCH ASSOCIATES

Muhetaer Aihaiti, *Postdoctoral Associate, ONR*
Pierre Beck, *Carnegie Fellow*[12]
Andrey Bekker, *Carnegie Fellow*
Razvan Caracas, *Carnegie Fellow and ONR Postdoctoral Associate*
Xiao-Jia Chen, *Postdoctoral Associate, DOE*
Jennifer Ciezak, *Postdoctoral Associate, Army Research Laboratory, Aberdeen Proving Grounds*[13]
Alexandre Corgne, *Carnegie Fellow, NSF, and NASA Postdoctoral Associate*[14]
Olga Degtyareva, *Carnegie Fellow*[15]
Jennifer L. Eigenbrode, *NASA Astrobiology Institute Associate*
Marc Fries, *Carnegie Fellow and Postdoctoral Associate JPL, and NASA Astrobiology Institute Associate*
Alexander Gavriliuk, *Postdoctoral Associate, DOE*[16]
Jennifer Jackson, *Carnegie Fellow*[17]
Steven Jacobsen, *Barbara McClintock Fellow, NSF*
Timothy Jenkins, *Postdoctoral Associate, DOE*
Shantanu Keshav, *Carnegie Fellow*[18]
Jung-Fu Lin, *Carnegie Fellow*
Giles Maule, *Postdoctoral Associate, NASA*
Penny L. Morrill, *Carnegie Fellow and NASA Astrobiology Institute Associate*[19]
Seth D. Newsome, *Postdoctoral Associate, NSF*[20]
Shuhei Ono, *Postdoctoral Associate, NASA*
Qing Peng, *Postdoctoral Associate, ONR*[21]
Angèle Ricolleau, *Postdoctoral Associate, NSF*[22]
Mathieu Roskosz, *Carnegie Fellow*
Matthew Schrenk, *Carnegie Fellow*[23]
Marcelo Sepliarsky, *Postdoctoral Associate, W&M ONR*[24]
Xianwei Sha, *Postdoctoral Associate, NSF*
Yang Song, *Harvard Postdoctoral Associate, NSF*
Elizabeth Cottrell Stevenson, *Carnegie Fellow*[25]
Sergey Tkachev, *Carnegie and CDAC*[26]
Jan Vorberger, *Carnegie Fellow*[27]
Heather Watson, *Carnegie Fellow*
Zhigang Wu, *William and Mary Postdoctoral Associate, ONR*[28]
Hikaru Yabuta, *Carnegie Fellow*[29]
Chih-Shiue Yan, *Postdoctoral Associate, NSF*

PREDOCTORAL FELLOWS AND PREDOCTORAL RESEARCH ASSOCIATES

Yu-Chun Chen, *NSF Associate-Technician*
Matthieu Galvez, *Personal Funds*[31]
Patrick Griffin, *NAI Associate, Prewitt-Hazen Gift Fund*[32]
Shih-Shian Ho, *NSF Associate*
Yann Le Gac, *Personal Funds*[30]
Rebecca Martin, *MSFC and ASTID Associate*
Rachel Schelble, *Carnegie Fellow*

Maia Schweizer, *ASTID and NASA Astrobiology Institute Associate*
Verena Starke, *NASA Marshall Space Flight Center Associate*
Yu Wang, *NSF Associate*[33]

RESEARCH INTERNS

Cheng Chin, *Columbia University*
Jennifer Cotton, *Brandeis University*
Ben Haugen, *University of Colorado*
Seth Jacobsen, *Cornell University*
Meredith Langstaff, *University of Chicago*
Elizabeth Monohan, *University of Massachusetts*
Frances Reid, *Carleton College*
Sonali Shukla, *NYU/Columbia University*
Erica Staehling, *Bucknell University*
Robert Thomas, *University of Maryland*

HIGH SCHOOL STUDENTS

Debbie Cheng, *Montgomery Blair High School*
Daniel Cohen, *Yeshiva of Greater Washington*
Jacob Cohen, *Yeshiva of Greater Washington*
Minh-Phuong Huynh-Le, *Montgomery Blair High School*
Andrew Kung, *Montgomery Blair High School*
Timothy Peng, *Montgomery Blair High School*

SUPPORTING STAFF

Maceo T. Bacote, *Building Engineer*[34]
Gary A. Bors, *Building Engineer*[34]
Valance Brenneis, *Laboratory Technician*
Bobbie L. Brown, *Instrument Maker*
Stephen D. Coley, Sr., *Instrument Shop Supervisor*
Phillip Davis, *Accounts Payable Specialist*[35]
Roy R. Dingus, *Facility Manager*[34]
Pablo D. Esparza, *Maintenance Technician*[34]
Allison Gale, *Laboratory Technician*
David J. George, *Electronics Technician*
Christos G. Hadidiacos, *Electronics Engineer*
Claire Hardy, *Technical Secretary*[49]
Shaun J. Hardy, *Librarian*[34]
Stephen Hodge, *Instrument Maker*[36]
Garret Huntress, *Systems Administrator/ Systems Developer*
Marjorie E. Imlay, *Assistant to the Director*
William E. Key, *Building Engineer*[34]
Szczesny (Felix) Krasnicki, *CVD Senior Engineer*[37]
Joseph Lai, *CVD Laboratory Scientist*[38]
Jeff Lightfield, *Controller*[39]
Paul Meeder, *Accounting Manager*[41]
Trong Nguyen, *Assistant Controller*[42]
Morgan Phillips, *Administrative Assistant*
Pedro J. Roa, *Maintenance Technician*[34]
Susan A. Schmidt, *Administrative Assistant*[43]
Haiyun (Kevin) Shu, *CVD, CDAC Laboratory Technician*[44]
Susan Southard, *Grants Officer*[45]
John M. Straub, *Business Manager*[46]
Andrew M. Ullman, *Laboratory Technician*
Merri Wolf, *Library Technical Assistant*[34]
Thomas Yu, *CVD, CDAC Laboratory Technician*[47]
Paula Zelanko, *Laboratory Technician*[48]

VISITING INVESTIGATORS

Hans Amundsen, *Physics of Geological Processes Institute, Norway*
Gretchen K. Benedix, *Smithsonian Institution*
Liane G. Benning, *University of Leeds, London*
Constance M. Bertka, *American Association for the Advancement of Science*
Lauren Borkowski, *William and Mary College*
Dina M. Bower, *Old Dominion University*
Kevin Burke, *University of Houston*[34]
Christopher L. Cahill, *George Washington University*
Aaron Celestian, SUNY, *Stony Brook*
Nancy Chabot, *The Johns Hopkins University, Applied Physics Laboratory*
Jinyang Chen, *Guangzhou Institute of Geochemistry, Chinese Academy of Sciences*
I. Ming Chou, *U.S. Geological Survey*
Albert S. Colman, *University of Maryland Biotechnology Institute, Baltimore*
Pamela G. Conrad, *Jet Propulsion Laboratory*
Catherine Corrigan, *National Museum of Natural History, Smithsonian Institution*
William B. Daniels, *University of Delaware*
Valentina Degtyareva, *Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka*
Lars Ehm, *SUNY, Stony Brook*
Mikhail Eremets, *Max Planck Institute for Chemistry, Mainz, Germany*
Joseph Feldman, *U.S. Naval Research Laboratory*
Timothy Filley, *Purdue University*
Yuri Freiman, *Verkin Institute for Low-Temperature Physics and Engineering, Ukrainian Academy of Sciences, Kharkov*
Friedemann Freund, *NASA Ames Research Center*
Alexander Gavrilyuk, *Institute for High Pressure Physics, Troitsk, Russia*
Harry W. Green, *University of California, Riverside*[34]
Wojciech Groçhala, *University of Warsaw, Poland*
Gudmundur H. Gudfinnsson, *University of Texas at Dallas*
John M. Hanchar, *George Washington University*
Bruce Jakosky, *Laboratory for Atmospheric and Space Physics, University of Colorado*[34]
Haemyeong Jung, *University of California, Riverside*
Guk Lac Kim, *Smithsonian Institution*
Yajie Lei, *George Washington University*
Hui Li, *Beijing Synchrotron Radiation Facility, Institute of High Energy Physics*
Jie Li, *University of Illinois, Urbana-Champaign*
Tianfu Li, *Chinese Academy of Geological Sciences*
Amy Y. Liu, *Georgetown University*
Haozhe Liu, *Institute of Physics, Chinese Academy of Sciences, Beijing*
Jing Liu, *Institute of Physics, Chinese Academy of Sciences, Beijing*
Jaime Marian, *California Institute of Technology*
Hidecki Masago, *University of Tokyo*
Kiyoto Matsuishi, *University of Tsukuba, Japan*
Timothy J. McCoy, *Smithsonian Institution*
Harold Morowitz, *George Mason University*[34]
Satoshi Nakano, *Tokyo Institute of Technology*
Yoshihide Ogasawara, *Waseda University, Japan*
Takuo Okuchi, *Nagoya University, Japan*
Christian Ostertag-Henning, *University of Muenster, Germany*
Simon Nicholas Platts, *University of California, Santa Cruz*
Yu S. Ponosov, *Institute of Metal Physics, Russia*
Robert L. Post, *Research Technology Associates, Washington, D.C.*
Dean C. Presnall, *University of Texas at Dallas*
Charles T. Prewitt, *Tucson, Arizona*
Huw Rowlands, *Blue Sky Project Solutions, United Kingdom*
Mikhail Sakharov, *Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka*
Chrystèle Sanloup, *Laboratoire MAGIE, Université Pierre et Marie Curie, Paris*
Barbara Smallwood, *University of Southern California*
Gerd Steinle-Neumann, *Bayerisches Geoinstitut, University of Bayreuth, Germany*
Mikhail Strzhemechny, *Verkin Institute for Low-Temperature Physics and Engineering, Ukrainian Academy of Sciences, Kharkov*
Dimitri A. Sverjensky, *The Johns Hopkins University*
Valery Terwilliger, *Smithsonian Institution*
Noreen C. Tuross, *Harvard University*
Yuchiro Ueno, *Tokyo Institute of Technology*
James A. Van Orman, *Case Western Reserve University*
Qingchen Wang, *Chinese Academy of Sciences, Guangzhou*
Wansheng Xiao, *Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou*
Yukihiro Yoshimura, *National Defense Academy, Japan*
Hak Nan Yung, *Chinese Academy of Sciences, Guangzhou*
Xiaowei Zeng, *George Washington University*
Yi-Gang Zhang, *Academia Sinica, China*
Zeming Zhang, *Academia Sinica, China*
Guangtian Zou, *Center for Superhard Materials, Jilin University, Changchun, China*

[1]From July 1, 2005
[2]To September 15, 2005
[3]From July 1, 2005
[4]From March 1, 2006
[5]To August 31, 2005
[6]To October 31, 2005
[7]To August 31, 2005
[8]From September 1, 2005
[9]From January 16, 2006
[10]To June 30, 2005
[11]From December 15, 2005
[12]From January 9, 2006
[13]From October 21, 2005
[14]To December 19, 2005
[15]To January 15, 2006
[16]From April 1, 2006
[17]From October 24, 2005
[18]To January 4, 2006
[19]From August 1, 2005
[20]From April 1, 2006
[21]From December 1, 2005
[22]From January 15, 2006
[23]From October 1, 2005
[24]From April 1, 2006, to June 1, 2006
[25]From September 1, 2005
[26]From January 1, 2006
[27]From July 5, 2005
[28]To January 24, 2006
[29]From July 5, 2005
[30]From March 1, 2006
[31]From March 5, 2006
[32]From September 20, 2005
[33]From November 1, 2005
[34]Joint appointment with DTM
[35]From April 13, 2006
[36]From April 1, 2006
[37]From August 1, 2005
[38]From October 24, 2005

DEPARTMENT OF GLOBAL ECOLOGY
First row (left to right): Bob Haxo, Jan Brown, Chris Field, Ken Caldeira, Joe Berry, Greg Asner, and Halton Peters. Second row (left to right): Maoyi Huang, Mary Smith, Jason Funk, Alison Appling, Linda Longoria, Claire Lunch, Yuka Estrada, Ben Houlton, Todd Tolbeck, Kim Nicholas Cahill, Larry Giles, and Ismael Villa. Back row (left to right): Angelica Vazquez, David Knapp, Paulo Oliveira, Noel Gurwick, Ulli Seibt, Eben Broadbent, George Merchant, and Glenn Ford.

[39]From February 1, 2006
[40]From April 15, 2006
[41]To January 5, 2006
[42]From April 19, 2006
[43]Retired June 30, 2006
[44]From July 1, 2005
[45]To March 15, 2006
[46]To January 5, 2006
[47]From October 25, 2005
[48]To September 1, 2005
[49]From June 5, 2006

Global Ecology

RESEARCH STAFF MEMBERS
Gregory Asner
Joseph A. Berry
Kenneth Caldeira
Christopher B. Field, *Director*

POSTDOCTORAL FELLOWS AND ASSOCIATES
Natalie Boelman, *Carnegie Research Fellow*[1]
Benjamin Houlton, *Princeton University*[2]
Maoyi Huang, *University of California, Berkeley*[3]
Halton Peters, *Stanford University*[4]
Ulrike Seibt, *Marie Curie International Fellowship*[5]

PREDOCTORAL FELLOWS AND ASSOCIATES
Kim Nicholas Cahill, *Stanford University*
Jason Funk, *Stanford University*
Noel Gurwick, *Cornell University*
John Juarez, *Stanford University*
Claire Lunch, *Stanford University*
Carolyn Snyder, *Stanford University*
Winston Wheeler, *Stanford University*[6]
Adam Wolf, *Stanford University*

SUPPORTING STAFF
Alison Appling, *Laboratory Technician*[7]
Eben Broadbent, *Laboratory Technician*
Christopher Carlson, *Laboratory Assistant*[8]
Kimberly Carlson, *Laboratory Assistant*[9]
Yair Chever, *Laboratory Assistant*[10]
Yuka Estrada, *Laboratory Technician*
Lawrence Giles, *Senior Laboratory Technician*
Robert Haxo, *Laboratory Technician*
Matthew Jones, *Laboratory Technician*[11]
David Knapp, *Senior Laboratory Technician*
David Kroodsma, *Laboratory Technician*[12].
Melissa Kunz, *Laboratory Assistant*[13]
Linda Longoria, *Administrative Assistant*
Robin Martin, *Laboratory Technician*
George Merchant, *Senior Programmer*
Astasia Meyers, *Intern*[14]
Ryan Mudd, *Laboratory Assistant*[15]
Paulo Oliveira, *Laboratory Technician*
Rebecca Raybin, *Laboratory Assistant*[16]
Todd Tobeck, *Laboratory Coordinator*
Tim Varga, *Laboratory Assistant*[17]

[1]To June 30, 2006
[2]From January 2, 2006
[3]From July 5, 2005
[4]From January 2, 2006
[5]To June 30, 2006
[6]To December 15, 2005
[7]To May 1, 2006
[8]From June 19, 2006
[9]To June 2, 2006
[10]From May 1, 2006
[11]From May 29, 2006
[12]To August 31, 2005
[13]From June 19, 2006
[14]From June 1, 2005, to August 31, 2005
[15]From January 2, 2006, to June 30, 2006
[16]From September 26, 2005
[17]From July 6, 2005

The Observatories

RESEARCH STAFF MEMBERS
Alan Dressler
Wendy Freedman, *Director*
Luis Ho
Patrick McCarthy
Andrew McWilliam
John Mulchaey
Augustus Oemler, Jr., *Director Emeritus*
Eric Persson
George Preston, *Director Emeritus*
Michael Rauch
Allan Sandage, *Staff Member Emeritus*
François Schweizer
Leonard Searle, *Director Emeritus*
Stephen Shectman
Ian Thompson
Ray Weymann, *Director Emeritus*

RESEARCH ASSOCIATES
Dan Kelson, *Staff Associate*
Barry Madore, *Senior Research Associate*

TECHNICAL STAFF MEMBERS
Matt Johns, *Associate Director of the Observatories*
Alan Uomoto, *Magellan Technical Manager*

POSTDOCTORAL FELLOWS AND ASSOCIATES
Kurt Adelberger, *Carnegie Fellow*[1]
Edo Berger, *Carnegie-Princeton Hubble Fellow*
Samuel Boissier, *Postdoctoral Associate*[2]
Christopher Burns, *Postdoctoral Associate*[3]
Jeffrey Crane, *Postdoctoral Associate*
Jeremy Darling, *Carnegie Fellow*[4]
Marla Geha, *Hubble Fellow*
Armando Gil de Paz, *Research Associate*[5]
Michael Gladders, *Hubble Fellow*[6]
Inese Ivans, *Carnegie-Princeton Fellow*[7]

Tesla Jeltema, *Postdoctoral Associate*
Ivo Labbé, *Carnegie Fellow*
Mark Seibert, *Postdoctoral Associate*[8]
Violet Taylor, *Postdoctoral Associate*[9]

LAS CAMPANAS RESEARCH STAFF

Mark Phillips, *Associate Director, Las Campanas Observatory*
Miguel Roth, *Director, Las Campanas Observatory*

LAS CAMPANAS FELLOWS AND ASSOCIATES

Gaston Folatelli, *Postdoctoral Fellow*
Joanna Thomas-Osip, *Magellan Research Associate*

LAS CAMPANAS VISITING INVESTIGATOR

Nidia Morell, *Visiting Scientist*

SUPPORT SCIENTIST

David Murphy, *Instrument Scientist*

EXTERNAL AFFAIRS, PASADENA

Arnold Phifer, *Regional Director of Advancement*[10]

SUPPORTING STAFF, PASADENA

Alex Athey, *Adaptive Optics Systems Engineer*
Alan Bagish, *Las Campanas Observatory Engineer*
Christoph Birk, *Data Acquisition Programmer*
Jerson Castillo, *Instrument Maker*
Ken Clardy, *Programmer*
Judith Collison, *Magellan Project Administrative Assistant/Assistant Business Manager*
Paul Collison, *Computer Systems Manager*
Jorge Estrada, *Electronics Technician*
John Grula, *Head Librarian, Information Services/ Publications Manager*
Tyson Hare, *Mechanical Engineer*
Earl Harris, *Shipping and Receiving Clerk*
Charles Hull, *Magellan Project Mechanical Engineer*
Silvia Hutchison, *Assistant to the Director*
Anne Kelly, *Research Assistant*[11]
Sharon Kelly, *Buyer*
Kathleen Koviak, *Data Analyst*[12]
Vincent Kowal, *Machine Shop Foreperson/ Instrument Maker*
Elsa Luna, *Controller*
Becky Lynn, *Secretary*
Luis Ochoa Ramirez, *Accounts Payable Specialist*[13]
Greg Ortiz, *Assistant, Buildings and Grounds*
Doreen Otsuka-Griffith, *Accounts Payable Clerk*[14]
Robert Pitts, *Assistant, Buildings and Grounds*
Scott Rubel, *Associate Facilities Manager*
Eli Slawson, *GMT Assistant*
Jeanette Stone, *Purchasing Manager*
Robert Storts, *Instrument Maker*
Gregory Walth, *Data Analyst*
Steven K. Wilson, *Facilities Manager*
Pamela Wyatt, *Research Assistant*

SUPPORTING STAFF, LAS CAMPANAS

Carolina Alcayaga, *Purchasing Officer*
Ricardo Alcayaga, *Mechanic*
Juan Alfaro, *GMT Site Maintenance Support*
Hernán Ángel, *Driver/Purchaser*
Jorge Araya, *Magellan Telescope Operator*[15]
Hector Balbontín, *Chef*
Jorge Bravo, *Magellan Instrument Specialist*
Patricio Carmona, *Janitor*
Pedro Carrizo, *Plumber*
Jilberto Carvajal, *El Pino Guard*
Jorge Castillo, *Paramedic*
Emilio Cerda, *Magellan Electronics Engineer*
Johnny Chavez, *Chef Assistant*
Carlos Contreras, *Science Support*
Angel Cortés, *Accountant*
Henry Cortés, Electrician
José Cortés, *Janitor*
Jorge Cuadra, *Mechanic Assistant*
Oscar Duhalde, *Mechanical Technician*[16]
Julio Egaña, *Painter*
Juan Espoz, *Mechanic*
Javier Fuentes, *GMT Site Testing Support*
Jaime Gómez, *Accounting Assistant*
Danilo González, *El Pino Guard*
Luis González, *Janitor*
Sergio González, *Science Support*
Javier Gutiérrez, *Mechanical Technician Assistant*
Luis Gutiérrez, *Mechanic*
Nelson Ibacache, *Mechanical Assistant*[16]
Marco Jara, *Chef*
Patricio Jones, *Magellan Electronics Engineer*
Marc Leroy, *Assisant Telescope Engineer*[16]
Leonel Lillo, *Carpenter*
Gabriel Martin, *Magellan Instrument Specialist*
Mauricio Martinez, *Magellan Telescope Operator*[17]
Marcos Medina, *Chef*
Miguel Méndez, *Mechanical Technician*[16]
Victor Meriño, *Magellan Instrument Specialist*[16]
Mario Mondaca, P/T *El Pino Guard*
César Muena, *GMT Site Testing Support*
Eric Muñoz, *Accountant*
Pascual Muñoz, *Chef*
Silvia Muñoz, *Business Manager*
Mauricio Navarrete, *Magellan Instrument Specialist*
Hernán Nuñez, *Magellan Telescope Operator*
Miguel Ocaranza, *Administrative Assistant*
Herman Olivares, *Night Assistant*
David Osip, *Magellan Instrumentation Scientist*
Jorge Para, *Mountain Superintendent*
Fernando Peralta, *Night Assistant*
Frank Perez, *Site Manager/ Telescope Engineer*[16]
Patricio Pinto, *Electronics Engineer*
Félix Quiroz, *Mechanical Technician*[16]
Andres Rivera, *Electronics Engineer*
Hugo Rivera, *Magellan Telescope Operator*
Javier Rivera, *Paramedic*
Honorio Rojas, *Water Pump Operator*
Jorge Rojas, *Janitor*
Felipe Sanchez, *Telescope Controls Programmer*[18]
Philip (Skip) Schaller, *Magellan Software Engineer*[19]
Gabriel Tolmo, *El Pino Guard*
Héctor Torres, *Mechanical Assistant*[16]
Manuel Traslaviña, *Heavy Equipment Operator*
Geraldo Vallardes, *Magellan Telescope Operator*
Sergio Vera, *Magellan Telescope Operator*[16]
José Soto Villagran, *Telescope Controls Programmer*[16]
Patricia Villar, *Administrative Assistant*

VISITING INVESTIGATORS

Elizabeth Adams, *Massachusetts Institute of Technology*
Fred Adams, *University of Michigan*
Gustavo Aguayo, *Universidad de Concepción, Chile*
Javier Alonso, *University of Michigan*
Pia Amigo, *Universidad Católica, Chile*
Julia Arias, *Universidad de La Serena, Chile*
Cristian Aruta, *Universidad Católica, Chile*
Michael Balogh, *University of Waterloo*
Rodolfo Barba, *Universidad de La Serena, Chile*
Wayne Barkhouse, *Harvard University, CfA*
Felipe Barrientos, *Universidad Católica, Chile*
Gustavo Baume, *Universidad Nacional de La Plata, Argentina*
George Becker, *California Institute of Technology*
Amy Bender, *University of Colorado*
Thomas Bensby, *University of Michigan*
John Blackslee, *Washington State University*
Guillermo Blanc, *Universidad de Chile*
Michael Blanton, *New York University*
Samuel Boissier, *L'Observatoire Astronomique de Marseille-Provence*
Luis Boldt, *Pontificia Universidad Católica de Chile*
Adam Bolton, *Harvard University, CfA*
Alceste Bonanos, *Department of Terrestrial Magnetism*
Roggie Boone, *Clemson University*
Alan Boss, *Department of Terrestrial Magnetism*
Ismael Botti, *Universidad de Chile*
Alexis Brandeker, *University of Toronto*
Carrie Bridge, *University of Toronto*
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Bailas Brown, *Harvard University, CfA*
Julia Bryant, *Harvard University, CfA*
Adam Burgasser, *Massachusetts Institute of Technology*
Scott Burles, *Massachusetts Institute of Technology*
Paul Butler, *Department of Terrestrial Magnetism*
Giovanni Carraro, *Universidad de Chile*
Marcio Catelan, *Universidad Católica, Chile*
Deepto Chakrabarty, *Massachusetts Institute of Technology*
Peter Challis, *Harvard University, CfA*
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Edgardo Costa, *Universidad de Chile*
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Emanuele Daddi, *National Oceanic and Atmospheric Administration*
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Ryan Folley, *Universidad Católica, Chile*
Duncan Forbes, *Swinburne University of Technology, Australia*
Harold Francke, *Universidad de Chile*
Cesar Fuentes, *Harvard University, CfA*

THE OBSERVATORIES 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.)

Rodrigo Fuentes, *Universidad de Concepción, Chile*
Gaspar Galaz, *Universidad Católica, Chile*
Roberto Gamen, *Universidad de La Serena, Chile*
Arti Garg, *Harvard University, CfA*
David Gilbank, *University of Toronto*
Armando Gil de Paz, *Universidad Complutense de Madrid, Spain*
Karl Glazebrook, *The Johns Hopkins University*
Matias Gomez, *Universidad de Concepción, Chile*
Anthony Gonzalez, *University of Florida*
Luis González, *Universidad de Chile*
Sebastián González, *Universidad Católica, Chile*
Nadya Gorlova, *University of Arizona*
Claudia Greco, *Universidad Católica, Chile*
Betsy Green, *University of Arizona*
Jenny Greene, *Harvard University, CfA*
Carl Grillmair, *California Institute of Technology*
Amanda Gulbis, *Massachusetts Institute of Technology*
Karl Haisch, *University of Michigan*
Steven Hale, *University of Birmingham, UK*
Jason Harris, *University of Arizona*
George Hau, *University of Durham, UK*
Ned Henry, *Harvard University, CfA*
Matthew Holman, *Harvard University, CfA*
Andy Howell, *University of Toronto*
Tracy Huard, *Harvard University, CfA*
Mark Huber, *Harvard University, CfA*
John Huchra, *Harvard University, CfA*
Adrienne Hunnaceck, *Massachusetts Institute of Technology*
Jason Ibarra, *San Francisco State University*
Rémy Indebetouw, *University of Virginia*
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Sheila Kannappan, *University of Arizona*
David Kaplan, *Massachusetts Institute of Technology*
Susan Kern, *Massachusetts Institute of Technology*
Robert Kirshner, *Harvard University, CfA*
Andrey Kratsov, *University of Chicago*
Claudia Kretchmer, *National Oceanic and Atmospheric Administration*
Kevin Krisciunas, *National Oceanic and Atmospheric Administration*
Woytek Krzeminski, *Copernicus Foundation*
Varsha Kulkarni, *University of South Carolina*
James Lauroesch, *Northwestern University*
Susan Lederer, *National Aeronautics and Space Administration*
Brian Lee, *University of Toronto*
Jae-Woo Lee, *Sejong University, Korea*
Samuel Lee, *Massachusetts Institute of Technology*
Roger Leiton, *Universidad de Concepción, Chile*
I-Hui Li, *University of Toronto*
Paulina Lira, *Universidad de Chile*
Sebastián López, *Universidad de Chile*
Mercedes López-Morales, *Department of Terrestrial Magnetism*
Ting Lu, *University of Waterloo*
Kevin Luhman, *Pennsylvania State University*
Steve Majewski, *University of Virginia*
Eric Mamajek, *Harvard University, CfA*
Massimo Marengo, *Harvard University, CfA*
Andre Martel, *The Johns Hopkins University*
Crystal Martin, *University of California, Santa Barbara*
Paul Martini, *Harvard University, CfA*
Karen Masters, *Harvard University, CfA*
Renée Mateluna, *Universidad de Concepción, Chile*
Mario Mateo, *University of Michigan*
José Maza, *Universidad de Chile*
Jeffrey McClintock, *Harvard University, CfA*
Joe Meiring, *University of South Carolina*
Felipe Menanteau, *The Johns Hopkins University*
René Méndez, *Universidad de Chile*
Gerhardt Meurer, *The Johns Hopkins University*
Trevor Miles, *University of Birmingham, UK*
Brek Miller, *University of Birmingham, UK*
Eliza Miller-Ricci, *Harvard University, CfA*
Dante Minitti, *Universidad Católica, Chile*
Maryam Modjaz, *Harvard University, CfA*
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Ivelina Moncheva, *University of Arizona*
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Chris Mullis, *University of Michigan*
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Robin Phillips, *University of Lethbridge, Canada*
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Woytek Pych, *Copernicus Foundation*
Hernán Quintana, *Universidad Católica, Chile*
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Marc Seigar, *University of California, Irvine*
Patrick Seitzer, *University of Michigan*
Rebecca Shafee, *Harvard University, CfA*
Scott Sheppard, *Department of Terrestrial Magnetism*
Min-Su Shin, *Princeton University*
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Robert Simcoe, *Massachusetts Institute of Technology*
Miguel Solis, *Universidad de Concepción, Chile*
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Christopher Stubbs, *Harvard University, CfA*
Mark Sullivan, *University of Toronto*
Andrew Szentgyorgyi, *Harvard University, CfA*
Nicolas Tejos, *Universidad de Chile*
Elena Terlevich, *Instituto Nacional de Astrofísica, Optica y Electrónica, Mexico*
Roberto Terlevich, *Instituto Nacional de Astrofísica, Optica y Electrónica, Mexico*
Gregory Tompkins, *University of Lethbridge, Canada*
Manuel Torres, *Harvard University, CfA*
Exequiel Treister, *Universidad de Chile*
Chad Trujillo, *Gemini Observatory, North*
Jonathan Trump, *University of Arizona*
Graham Verner, *University of Birmingham, UK*
Alexey Vikhlinin, *Harvard University, CfA*
Sylvain Villeux, *University of Maryland*
Shanil Virani, *Yale University*
Kaspar von Braun, *Department of Terrestrial Magnetism*
Saeqa Vrtilek, *Harvard University, CfA*
Kim Vy Tran, *Harvard University, CfA*
Matthew Walker, *University of Michigan*
Emily Wang, *Massachusetts Institute of Technology*
Junxian Wang, *University of Science and Technology of China*
Martin Ward, *University of Durham, UK*
Christopher Watson, *University of Sheffield, UK*
David Weaver, *Harvard University, CfA*
Alycia Weinberger, *Department of Terrestrial Magnetism*
Ben Weiner, *University of Maryland*
Hsiao Wen-Chen, *University of Chicago*
Jessica Werk, *University of Michigan*
Paul Westoby, *John Moores University, UK*
Grant Williams, *University of Arizona*
Kurtis Williams, *University of Arizona*
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Yujin Yang, *University of Arizona*
Howard Yee, *University of Toronto*
Erick Young, *University of Arizona*
Jaime Zamorano, *Universidad Complutense de Madrid, Spain*
Paula Zelaya, *Universidad Católica, Chile*
Manuela Zoccali, *Universidad Católica, Chile*

[1]To September 7, 2005
[2]To November 30, 2005
[3]From August 15, 2005
[4]To July 31, 2005
[5]To September 30, 2005
[6]To September 1, 2005, Carnegie Fellow; from September 1, 2005, Hubble Fellow
[7]From September 1, 2005
[8]From June 30, 2006
[9]From May 30, 2006
[10]From February 1, 2006
[11]From November 1, 2005, to June 21, 2006
[12]To December 19, 2005
[13]From March 20, 2006
[14]To January 31, 2006
[15]From August 30, 2005
[16]From July 1, 2005
[17]From September 27, 2005
[18]From November 1, 2005
[19]To February 8, 2006

Plant Biology

RESEARCH STAFF MEMBERS

M. Kathryn Barton
Winslow R. Briggs, *Director Emeritus*
David Ehrhardt
Wolf B. Frommer
Arthur R. Grossman
Seung Y. Rhee[1]
Christopher R. Somerville, *Director*
Shauna C. Somerville
Zhi-Yong Wang

ADJUNCT STAFF

Devaki Bhaya
Matthew Evans

VISITING INVESTIGATORS

Stephan Eberhard, *Institut de Biologie Physico Chimique, France*[2]
Agnes Harms, *University of Tübingen, Germany*[3]
Carlos Melo, *Universidade de Coimbra, Portugal*[4]
Jennifer Milne, *Stanford University*
Georgios Perrakis, *Wageningen University, Netherlands*[5]
Theodore Raab, *Stanford University*[6]
Susan Thayer, *Independent Researcher*[7]
Trevor Swartz, *University of California, Santa Cruz*

POSTDOCTORAL FELLOWS AND ASSOCIATES

Debbie Alexander, *Carnegie Fellow*
Shaun Bailey, *NSF Research Associate*[8]
Stefan Bauer, *DFG Fellow*[9], *Carnegie Fellow*[10]
Keren Bracha Drori, *NIH/HFSP Research Associate*[11]
Ginger Brininstool, *DOE Research Associate*[12]
Bhavna Chaudhuri, *NIH/HFSP Research Associate*
Shaolin Chen, *DOE Research Associate*[13]
Seth Debolt, *DOE Research Associate*[14]
Zhiping Deng, *NIH Research Associate*
Karen Deuschle, *Carnegie Fellow*[15]
John Emery, *NIH Research Associate*[16]
José Estevez, *DOE Research Associate*
Satyalinga Srinivas Gampala, *NIH Fellow*
David Gonzalez Ballester, *NSF Research Associate*[17]
Thorsten Hamman, *DFG Fellow*[12], *Carnegie Fellow*[18]
Mamatha Hanumappa, *NIH Research Associate*[19]
Jun-Xian He, *Carnegie Fellow*[20]
Friederika Hoermann, *HFSP Research Associate*[21]
Matthew Humphry, *NSF Research Associate*[22]
Chung-Soon Im, *NSF Research Associate*
Pablo Jenik, *Carnegie Fellow*
Thijs Kaper, *Carnegie Fellow*
Nicholas Kaplinsky, *NSF Research Associate*[23]
Oliver Kilian, *NSF Research Associate*[24]
Tae-Wuk Kim, *Carnegie Fellow*
Serry Koh, *Carnegie Fellow*
Sylvie LaLonde, *NIH Research Associate*
Shijun Li, *NSF Research Associate*[25]
Melisa Lim, *DOE Research Associate*
Loren Looger, *Koerber Fellow*
Dominique Loqué, *Carnegie Fellow*
Daniel Maclean, *NSF Research Associate*[26]
Rebecca McCabe, *DOE Research Associate*[27]
Jeffrey Moseley, *LSRF Fellow*[28], *GCEP Research Associate*[4]
Florence Mus, *DOE Research Associate*
Totte Niittyla, *Koerber Fellow*[9], *HFSP Fellow*[10]
Rieko Nishimura, *NSF Research Associate*[6]
Sakiko Okumoto, *Carnegie Fellow*
Staffan Persson, *Swedish Research Foundation Fellow*[29], *DOE Research Associate*[30]
Steve Pollock, *USDA Research Associate*[12]
Marcella Pott, *NSF Research Associate*
Brenda Reinhart, *NIH Research Associate*
Meghan Sharp, *NIH Research Associate*
Nakako Shibagaki, *USDA Research Associate*
Jeffrey Shrager, *NSF Research Associate*
Anne Steunou, *NSF Research Associate*
Yu Sun, *NIH Research Associate*
Hitomi Takanaga, *NIH Research Associate*
Wenqiang Tang, *DOE Research Associate*
Susan S. Thayer, *NSF Research Associate*[22]
Tong-Seung Tseng, *NSF Research Associate*
Chao-Jung Tu, *Carnegie Fellow*
Sonja Vorwerk, *DFG Fellow*[16]
Thomas Walk, *NSF Research Associate*[31]
Stephan Wenkel, *NIH Research Associate*[32]

DEPARTMENT OF PLANT BIOLOGY First row (left to right, standing): Reiko Nishimura, Hitomi Takanaga, Winslow Briggs, In-Seob Han. First row (left to right, sitting): Noah Whitman, Melisa Lim, Ying Gu, Joe Filla, Florence Mus, Miguel Carvalho, Jeffrey Moseley. First Row (standing on right): Shauna Somerville, Chris Somerville, Paul Sterbentz. Second row (left to right): Devaki Bhaya, Christian Voigt, Joshua Gendron, Kathi Bump, Matt Evans, Kathy Barton. Third row (left to right): Tanya Berardini, Jose Estevez, Donghui Li, Angelica Vazquez, Bhavna Chaudhuri, Julie Tacklind, Tom Meyer. Fourth row (left to right): Natalie Khitrov, Friederike Hoermann, Thijs Kaper, Jennifer Milne, Susan Cortinas, Sakiko Okumoto, Hitomi Takanaga, Tom Walk. Fifth row (sitting on left side): Debbie Alexander, Meghan Sharp, Totte Niittyla, Shengwei Zhu, Viktor Kirik, Sabine Mueller, Blaise Hamel, Nakako Shibagaki, Hulya Aksoy, Diane Chermak, Vanessa Swing. Fifth row (sitting on right side): Hartmut Foerster, Christophe Tissier, Christopher Wilks, Zhiping Deng, David Swarbreck.Sixth row (left to right): Arthur Grossman, Zhiyong Wang, Doug Simmons, Lisandra West, Glenn Ford, Mary Smith, Nik Pootakham, Evana Lee, Yu Sun, Natashia Reikel, Bob Muller, Shanker Singh, Ismael Villa, Anne Steunou, Miguel Carvalho. Back row (left to right): Tom Eckhart, Seth DeBolt, Andrew Carrol, Srini Gampala, Staffan Persson, Tae Wuk Kim, Stephan Wenkel, Wensheng Qin, Wenqiang Tang.

PREDOCTORAL FELLOWS AND ASSOCIATES

Hae-Young Cho, *Carnegie Research Associate*[4]
Michelle Facette, *Stanford University*
Joshua Gendron, *Stanford University*
Ida Lager, *University of Tübingen*[33], *HFSP Research Associate*[34]
Rebecca McCabe, *Stanford University*[28]
Alex Paredez, *Stanford University*
Monica Stein, *Stanford University*[26]

SUPPORTING STAFF

Stephane Bagneris, *Intern*[32]
Douglas Becker, *Technical Lead Curator*[35]
Tanya Berardini, *Curator*
Kathryn Bump, *Human Resources Specialist*
Huanjing Chen, *Laboratory Assistant*[29]
Diane Chermak, *Laboratory Technician*
Susan Cortinas, *Grants Administrator*
Ericka Fernquist, *Intern*[32]
Gabriele Fiene, *Laboratory Technician*
Joseph Filla, *Systems Administrator*
Hartmut Foerster, *Curator*
Glenn A. Ford, *Laboratory Manager*
Margarita Garcia-Hernandez, *Curator*
Radhika Garlapati, *Laboratory Assistant*[9]
Nathan Gendron, *Laboratory Assistant*
Renee Halbrook, *Laboratory Technician*
Blaise Hamel, *Intern*[9]
Adam Herman, *Intern*[36]
Melanie Hilpert, *Senior Laboratory Technician*[37]
Bi-Huei Hou, *Laboratory Technician*
Eva Huala, *Head Curator*
Chi Hsu, *Intern*[38]
Young Hsu, *Intern*[39]
Katica Ilic-Grubor, *Curator*
John Jacobson, *Greenhouse Assistant*
Natalie Khitrov, *Laboratory Technician*
Nadejda Kleimenova, *Laboratory Assistant*[36]
Aleksey Kleytman, *Assistant Curator*[40]
Ann Kuljian, *Laboratory Assistant*[28]
Iris Law, *REU Intern*[41]
Erik Lehnert, *Intern*[19]
Khar-Wai Lye, *Laboratory Technician*
John McGee, *Intern*[38]
Thomas Meyer, *Software Engineer*[42]
Dorianne Moss, *Laboratory Technician*
Robert Muller, *Technical Lead Curator*[43]
Suparna Mundodi, *Programmer*[16]
Anh Nguyen, *Intern*[44]
Dana Parmenter, *Research Technician*
Ryan Pham, *Intern*[45]
Patti Poindexter, *Laboratory Technician*
Shirin Rahmanian, *REU Intern*[46]
Leonore Reiser, *Curator*[28]
Blanca Rivas, *Dishwasher*
Antoinette Sero, *Laboratory Assistant*
David Simmons, *Laboratory Assistant*[47]

Lisa Simons, *Accounts Payable Specialist/ Receptionist*[48]
Jon Slenk, *Programmer*[4]
Mary A. Smith, *Business Manager*
Paul Sterbentz, *Facilities Manager*
Julie Tacklind, *Laboratory Assistant*
Deborah Tausch, *Financial Officer*
Christophe Tissier, *Curator*[32]
Miguela Torres, *Secretary/Accounts Payable*[49]
Azam Noorani Vatani, *Laboratory Assistant*
Angelica Vazquez, *Dishwasher*
Ismael Villa, *Facilities Assistant*
Renee Wang, *Accounts Payable Specialist*
Noah Whitman, *Laboratory Technician*[50]
Christopher Wilks, *Intern*
Christopher Wolf, *Intern*[9]
Matthew Woloszyn, *Intern*[9]
Chunxia Xu, *Programmer Technician*[51]
Thomas Yan, *Bioinformatics Intern*[52]
Daniel Yoo, *Programmer*[53]
Peifen Zhang, *Curator*
Brandon Zoeckler, *Assistant Curator*[54]

[1]From July 1, 2005
[2]To December 1, 2005
[3]To August 30, 2005
[4]From April 1, 2006
[5]From April 15, 2006
[6]From September 1, 2005
[7]From January 1, 2006
[8]From May 7, 2006
[9]To September 30, 2005
[10]From October 1, 2005
[11]From September 16, 2005
[12]To July 31, 2005
[13]From December 5, 2005
[14]From March 13, 2006
[15]To April 26, 2006
[16]To May 31, 2006
[17]From January 1, 2006, to June 30, 2006
[18]From August 1, 2005, to January 15, 2006
[19]To September 15, 2005
[20]To March 14, 2006
[21]From May 1, 2006
[22]To December 31, 2005
[23]To August 31, 2005
[24]From July 20, 2005
[25]To October 14, 2005
[26]To June 30, 2006
[27]From April 1, 2006, to May 5, 2006
[28]To March 31, 2006
[29]To January 31, 2006
[30]From February 1, 2006
[31]From January 9, 2006
[32]From June 1, 2006
[33]To February 28, 2006
[34]From March 1, 2006, to June 30, 2006
[35]To April 7, 2006
[36]From June 6, 2006
[37]To February 3, 2006
[38]From June 19, 2006
[39]From April 26, 2006
[40]To June 2, 2006
[41]To September 26, 2005
[42]From June 16, 2006
[43]From May 22, 2006
[44]From June 26, 2006
[45]To August 19, 2005
[46]To September 28, 2005
[47]From June 20, 2006
[48]From March 1, 2006
[49]To January 3, 2006
[50]From January 24, 2006
[51]To January 15, 2006
[52]To June 23, 2006
[53]To May 5, 2006
[54]To March 3, 2006

Terrestrial Magnetism

RESEARCH STAFF MEMBERS

L. Thomas Aldrich, *Emeritus*
Conel M. O'D. Alexander
Alan P. Boss
R. Paul Butler
Richard W. Carlson
John E. Chambers
John A. Graham, *Emeritus*
Erik H. Hauri
David E. James
Alan T. Linde
Larry R. Nittler
I. Selwyn Sacks
Sara Seager
Steven B. Shirey
Paul G. Silver
Sean C. Solomon, *Director*
Fouad Tera, *Emeritus*
Alycia J. Weinberger
George W. Wetherill, *Director Emeritus*

SENIOR FELLOW

Vera C. Rubin

RESEARCH SCIENTIST

James Y.-K. Cho[1]

POSTDOCTORAL FELLOWS AND ASSOCIATES

Alceste Z. Bonanos, *Vera C. Rubin Fellow*[2]
Maud Boyet, *Carnegie Fellow*[3]
Henner Busemann, *NASA Astrobiology Institute Fellow and NASA Associate*
Fred Ciesla, *Carnegie Fellow*[4]
Catherine M. Cooper, *Carnegie Fellow*[5]
John H. Debes, *NASA Associate*[6]
Catherine N. Foley, *NASA Associate*[7]
Catherine A. Hier-Majumder, *MESSENGER Associate*
Hannah Jang-Condell, *NASA Astrobiology Institute Fellow and NASA Associate*
Katherine A. Kelley, *Carnegie Fellow*[8]
Mercedes López-Morales, *Carnegie Fellow and NASA Astrobiology Institute Fellow*
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Alison M. Shaw, *NSF Associate*[14]
Scott S. Sheppard, *Hubble Fellow*
Taka'aki Taira, *C. V. Starr Fellow*
Margaret Turnbull, *NASA Astrobiology Institute Research Associate*
Kaspar von Braun, *NASA Astrobiology Institute Fellow*[15]
Lara S. Wagner, *Harry Oscar Wood Fellow*[16]
Linda M. Warren, *Harry Oscar Wood Fellow and NSF Associate*
Dayanthie S. Weeraratne, *NSF Associate*

PREDOCTORAL FELLOWS AND ASSOCIATES

Lindsey S. Chambers, *University of California, Santa Cruz*
Saad S. B. Haq, *State University of New York, Stony Brook*
Ben Hood, *University of St. Andrews*

RESEARCH INTERNS

Aditi Bhaskar, *Brown University*
Amanda Hughes, *Washington and Lee University*
Meredith Langstaff, *University of Chicago*
Elizabeth Monahan, *University of Massachusetts, Amherst*
Jennifer Ortega, *University of Missouri, Columbia*
Sonali Shukla, *Vanderbilt University*
Erica Staeling, *Bucknell University*
Max Zinner, *Mary Institute and St. Louis Country Day School*

SUPPORTING STAFF

Michael J. Acierno, *IT/IS Manager/Systems Engineer*
Maceo T. Bacote, *Building Engineer*[17]
Richard L. Bartholomew, *Machinist, Instrument Maker*
Jay E. Bartlett II, *Machinist*[18]
Gary A. Bors, *Building Engineer*[17]
Peter G. Burkett, *Field Seismologist*[19]
Alicia R. Case, *Administrative Assistant*[20]
Alexis Clements, *Web and Publications Coordinator*[21]
Michael Crawford, *Machinist, Instrument Maker*[22]
Jerry W. Davis, *Apprentice Building Engineer*[23]
Roy R. Dingus, *Facility Manager*[17]
Janice Scheherazade Dunlap, *Assistant to the Director*
Pablo D. Esparza, *Maintenance Technician*[17]
Steven Golden, *Field Seismologist*[24]
Shaun J. Hardy, *Librarian*[17]
Mary F. Horan, *Geochemistry Laboratory Manager*
Sandra A. Keiser, *Scientific Computer Programmer/ Systems Manager*
William E. Key, *Building Engineer*[17]
Michelle B. Martin, *Administrative Assistant*
P. Nelson McWhorter, *Senior Instrument Maker, Shop Manager*
Timothy D. Mock, *Mass Spectrometry Laboratory Manager*
Ben K. Pandit, *Electronics Laboratory Manager*
Daniela D. Power, *Geophysical Research Assistant*
Pedro J. Roa, *Maintenance Technician*[17]
Brian P. Schleigh, *Electronic Design Engineer*
Terry L. Stahl, *Fiscal Officer*
Jianhua Wang, *Ion Microprobe Research Specialist*
Tao (Kevin) Wang, *Fiscal Assistant*
Merri Wolf, *Library Technical Assistant*[17]

DEPARTMENT OF TERRESTRIAL MAGNETISM, NOVEMBER 2006. First row (left to right): Sergei Ipatov, David James, Dayanthie Weeraratne, Merri Wolf, Isamu Matsuyama, Kevin Wang, Jianghui Ji, Sara Seager, Shaun Hardy, Steven Shirey, Ivan Savov, Alan Boss. Second row (left to right): Mary Horan, Lan-Anh Nguyen, Catherine Cooper, Brian Schleigh, Steven Golden, Alicia Case, Ben Pandit, Alceste Bonanos, Hannah Jang-Condell, Janice Dunlap, Vera Rubin, Linda Warren, Alycia Weinberger, Nelson McWhorter. Third row (left to right): Brenda Eades, Mike Crawford, Sean Solomon, Scott Sheppard, Richard Bartholomew, Lara Wagner, Maureen Long, Roy Dingus, Lindsey Chambers, Stephen Richardson, Fred Ciesla. Fourth row (left to right): Paul Butler, Timothy Mock, Selwyn Sacks, Conel Alexander, Alan Linde, Henner Busemann, Bill Key, Gary Bors, Taka'aki Taira, Terry Stahl, Paul Silver, John Chambers, Erik Hauri, Ben Hood, Thomas Ruedas, Daniela Power, John Graham.

VISITING INVESTIGATORS

Mark D. Behn, *Woods Hole Oceanographic Institution*
Craig R. Bina, *Northwestern University*
Ingi Th. Bjarnason, *University of Iceland*
Jay A. Brandes, *Skidaway Institute of Oceanography*
Kevin C. Burke, *University of Houston*[17]
James Y.-K. Cho, *University of London*
Inés L. Cifuentes, *Carnegie Institution of Washington*
Roy S. Clarke, Jr., *Smithsonian Institution, National Museum of Natural History*
Lucy M. Flesch, *Purdue University*
Matthew J. Fouch, *Arizona State University*
Jay A. Frogel, *University of Maryland, College Park*
Stephen S. Gao, *Kansas State University, Manhattan*
Harry W. Green II, *University of California, Riverside*[17]
William E. Holt, *State University of New York, Stony Brook*
Emilie E. E. Hooft Toomey, *University of Oregon*
Bruce M. Jakosky, *University of Colorado*[17]
Jianghui Ji, *Purple Mountain Observatory, Chinese Academy for Science*
Catherine L. Johnson, *Scripps Institution of Oceanography*
Karl Kehm, *Washington College*
Christopher R. Kincaid, *University of Rhode Island*
Carolina Lithgow-Bertelloni, *University of Michigan*
Gabriela Mallén-Ornelas, *Harvard-Smithsonian Center for Astrophysics*
Patrick J. McGovern, *Lunar and Planetary Institute*
Harold J. Morowitz, *George Mason University*[17]
Elizabeth A. Myhill, *Marymount University*
Fenglin Niu, *Rice University*
L. Jeremy Richardson, *NASA Goddard Space Flight Center*
Stephen H. Richardson, *University of Cape Town*
Raymond M. Russo, Jr., *University of Florida*
Paul A. Rydelek, *University of Memphis*
Martha K. Savage, *Victoria University, New Zealand*
Yang Shen, *University of Rhode Island*
David W. Simpson, *Incorporated Research Institutions for Seismology*
J. Arthur Snoke, *Virginia Polytechnic Institute and State University*
Erik O. Sturkell, *University of Iceland*
Douglas R. Toomey, *University of Oregon*
Tetsuo Takanami, *Hokkaido University*
Nathalie J. Valette-Silver, *National Oceanographic and Atmospheric Administration*
John C. VanDecar, *Nature Magazine, London*
Suzan van der Lee, *Northwestern University*
Elisabeth Widom, *Miami University, Ohio*
Cecily J. Wolfe, *University of Hawaii*
Hongfu Zhang, *University of Hong Kong*

[1]To August 31, 2005
[2]From September 5, 2005
[3]To November 5, 2005
[4]From January 3, 2006
[5]From September 6, 2005
[6]From September 6, 2005
[7]To August 31, 2005
[8]To August 31, 2005
[9]From October 3, 2005
[10]From February 1, 2006
[11]To September 1, 2005
[12]From September 6, 2005
[13]To December 31, 2005
[14]To December 31, 2005
[15]To October 4, 2005
[16]From November 1, 2005
[17]Joint appointment with Geophysical Laboratory
[18]To January 15, 2006
[19]To March 15, 2006
[20]From August 29, 2005
[21]To September 2, 2005
[22]From November 7, 2005
[23]From September 14, 2005, to January 9, 2006
[24]From March 1, 2006

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