

CARNEGIE INSTITUTION OF WASHINGTON

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At the Frontiers of Science

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At the Frontiers of Science

The President's Report July 1, 2004-June 30, 2005

CARNEGIE INSTITUTION
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James Parmelee, 1917-1931

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.

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THE PRESIDENT'S COMMENTARY

"... we have sought to nurture basic science that holds great promise, if successful, but that may be far from the mainstream because of the high risk of failure, the difficulty of the problem, or the need for extended effort before results can be obtained. It is exactly such work that is likely to lead to transformational change—to significant and startling advances." —RICHARD A. MESERVE



Carnegie president
Richard Meserve.

IMAGE COURTESY JIM JOHNSON.

In many respects, the U.S. is at a crossroads. The nation faces divisive issues concerning Iraq, tax policy, budget priorities, health care, and many other matters. Some of the controversies involve science, including issues relating to intelligent design, stem cell research, and climate change. All of these matters deserve careful and thoughtful response. But in my view, there is one issue that is of singular importance because it affects the nation's ability, either directly or indirectly, to respond to all of these matters. That issue is the capacity of the U.S. to harness science and technology to nurture continuing American success in the 21st century. I shall focus here on this issue and its relation to the Carnegie Institution.

It can reasonably be argued that the human condition advanced more significantly over the 20th century than over the entire remainder of history. This change was due in large measure to significant scientific and technical accomplishments. The harnessing of electricity has allowed illumination during the night and provided clean energy for use in the home and at work. In fact, nearly 16% of the world's electrical supply (20% in the U.S.) comes from nuclear fission, a form of energy that we did not even know existed at the turn of the 20th century. Automobile and aeronautical technology and highway development facilitated rapid transportation and have changed lifestyles around the globe. Water distribution and sanitization have provided safe and abundant drinking-water supplies that were unknown to our forebears. Medical advances have eradicated various diseases and substantially lengthened the average American's life span. Agricultural mechanization and biotechnology have enhanced the food supply.

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The revolution in electronics has fundamentally altered communications and changed the way we amuse and educate ourselves. The Internet has provided ready access to an enormous range of information from anywhere in the world with a few mouse clicks. In short, our lives are vastly different from those who lived only a century ago. The typical American has access to opportunities and capabilities that were beyond the reach, or even the imagination, of the wealthiest individuals in previous centuries. However, the treasure that science can yield is far from fully exploited; there is the promise of more startling change to come.

Progress notwithstanding, science and technology have also presented us with challenges. Technological advances, for instance, have created environmental problems—most notably, air and water pollution, as well as climate change. But science has simultaneously given us the capacity, if we have the will, to understand and limit adverse impacts. Any fair accounting of the balance sheet would show that science and technology have advanced the human condition far more than they have threatened it.

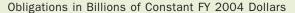
The U.S. has led the world in creating and implementing many of the past century's technical developments, yielding an economic and strategic strength that is vastly disproportionate to our population. But there are problems on the horizon. Globalization is presenting a challenge to our position as a world leader. Jobs are flowing overseas to lower-wage skilled workers even, through modern communications, for service work.² In technical fields in which the U.S. has long enjoyed an edge, we now face competition from countries such as China and India, which are growing quickly and whose workers' skills are expanding rapidly.

Of course, we should welcome the improvement of standards of living around the globe that has accompanied these changes. Such advances serve humanitarian purposes in that they enable more people to escape poverty, hunger, and disease. Moreover, these advances also nurture a web of economic, political, and personal connections that can minimize distrust, enhance cumulative prosperity, and further the prospects for understanding and peace. Nonetheless, there is reason to worry about the future position of the U.S. in a world in which the technological advantage that we have long enjoyed is diminished. It is not inconsistent to hope for advances in the rest of the world while simultaneously seeking to maintain our role as a scientific and technological pathfinder and thereby to maintain our leadership position.

With the encouragement of several members of Congress, the National Academies established a committee to examine the challenge of ensuring a prosperous future for the U.S. The committee was chaired by Norman Augustine, the retired chairman and CEO of Lockheed Martin, and included numerous prominent members from the academic and business communities.³ Its report, *Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, includes a careful analysis of the role of science and technology in maintaining the vitality of the U.S., and sets out a number of actions that the U.S. should take to preserve its position as a global power.

In the face of growing scientific and technical capacities around the globe, the Augustine committee urged action to enhance K-12 science and mathematics education, to sustain science and engineering

TRENDS IN FEDERAL RESEARCH BY DISCIPLINE, FY 1970-2004



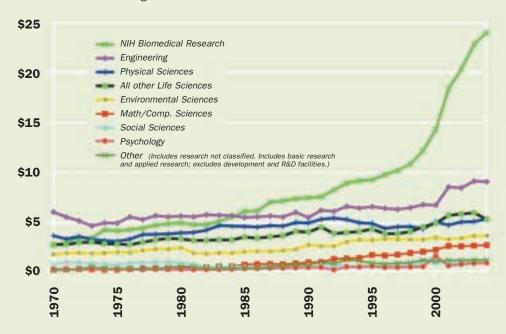


FIGURE 1

Trends in federal spending since 1970 show that most of the growth in scientific support has been in the life sciences.

IMAGE COURTESY AMERICAN
ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, AAAS.

Life sciences—split into NIH support for biomedical research and all other agencies' support for life sciences. Source: NSF, *Federal Funds for Research and Development FY 2002, 2003, and 2004,* 2004. FY 2003 and 2004 data are preliminary. Constant-dollar conversions based on OMB's GDP deflators. October 2004 © AAAS.

research, to recruit the best and the brightest students to higher education in science and engineering, and to provide incentives for innovation. The report provides a clear, albeit very challenging, set of recommendations to protect our country's future. As this is written, it remains to be seen if we have the political will, or the financial resources, to pursue the committee's advice.

I shall focus on one recommendation that bears directly on the Carnegie Institution.⁴ The committee highlights the importance of strengthening the commitment to long-term basic research, noting that such work is "transformational," in that it can yield sweeping change. The committee observes that the private sector cannot be expected to invest adequately in such basic research for many understandable reasons: the benefits may not be captured by the private sponsor, the work is risky, and shareholder pressure for short-term results discourages such long-term investments. There is a role for government support, but

U.S R&D AS PERCENT OF GROSS DOMESTIC PRODUCT Total Federal R&D - 1953-2003 3.0% FIGURE 2 2.5% The total federal ■ Total Federal R&D research and development spending has 2.0% declined in recent years as a percentage of U.S. gross 1.5% domestic product. IMAGE COURTESY AMERICAN ASSOCIATION FOR THE ADVANCE-1.0% MENT OF SCIENCE, AAAS. 0.5% 0.0% 1953 1958 1968 1973 1998 2003

the trends in government funding are not encouraging. Although federal support for research has grown in real terms over several decades, nearly all of the growth has been in the life sciences (Fig. 1). And, in the face of an expanding economy, federal support of research and development has declined as a percentage of U.S. gross domestic product by a factor of two over the course of several decades (Fig. 2). The current budget deficits make it difficult to respond to this situation. But, to preserve the nation's future, the committee strongly recommends a very dramatic increase in investment in basic research.

Source: NSF, Division of Science Resources Statistics. 2002 and 2003 data are preliminary. February 2004 @ AAAS.

The committee's recommendation highlights an emphasis that has been the Carnegie Institution's guiding purpose since our beginning over a century ago. Andrew Carnegie's deed of trust provides that the institution "shall in the broadest and most liberal manner encourage investigation, research and discovery" and thereby enable "the application of knowledge to the improvement of mankind." In defining the mission of the organization, Andrew Carnegie directed that it should "discover the exceptional man in every

department of study wherever and whenever found . . . and enable him to make the work for which he seems specially designed his life work." Consistent with this philosophy, we have sought to nurture basic science that holds great promise, if successful, but that may be far from the mainstream because of the high risk of failure, the difficulty of the problem, or the need for extended effort before results can be obtained. It is exactly such work that is likely to lead to transformational change—to significant and startling advances. In short, the type of research that the Augustine committee concludes is of singular importance to the nation has been and will continue to be a hallmark of Carnegie's scientific efforts.

Carnegie has a proud tradition in the pursuit of basic science, as a consideration of the work of Carnegie scientists reveals. Some of Carnegie's researchers are well known:

- Edwin Hubble, who revolutionized astronomy with his discovery that the universe is expanding and that there are galaxies other than our own Milky Way;
- Charles Richter, who created the earthquake measurement scale;
- Barbara McClintock, who won the Nobel Prize for her early work on patterns of genetic inheritance;
- Alfred Hershey, who won the Nobel Prize for determining that DNA, not protein, harbors the genetic recipe for life;
- Vera Rubin, who was awarded the Presidential Medal of Science for her work confirming the existence of dark matter in the universe; and
- Andrew Fire, who with colleagues elsewhere opened up the world of RNA interference, which was acclaimed by *Science* magazine as the Breakthrough of the Year in 2002.

Many other Carnegie scientists continue work at the forefront of discovery. In the following pages of this Year Book, we sample some of the startling scientific advances from each of Carnegie's departments over the past year. These examples give a flavor of the vibrancy of our institution.

As shown by the report of the Augustine committee, the research that Carnegie pursues is of a type that is central to the health of the nation. Although we can be only one participant in what must be a broad national effort, we will continue to strive to be an important contributor. Many exciting discoveries lie ahead. The best is yet to come for the Carnegie Institution, for the nation, and for the world.

Richard A. Meserve December 21, 2005

George Constable and Bob Somerville, A Century of Innovation: Twenty Engineering Achievements That Transformed Our Lives (Washington, D.C.: National Academy of Engineering, Joseph Henry Press, 2003).

² Thomas Friedman, The World Is Flat: A Brief History of the Twenty-First Century (New York: Farrar, Straus and Giroux, 2005).

³ The study was chartered by the Academies' Committee on Science, Engineering, and Public Policy (COSEPUP). At the time the study was started, my predecessor as Carnegie president, Maxine Singer, served as its chair. I am a member of COSEPUP.

⁴ The committee's recommendations relating to K-12 education also bear on Carnegie's efforts. Our educational activities are discussed in this Year Book.

Carnegie Institution

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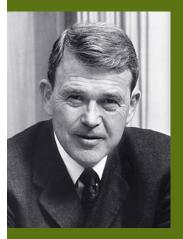
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WILLIAM R. HEWLETT



The legendary electronics inventor, cofounder of Hewlett-Packard Company, and National Medal of Science winner William R. (Bill) Hewlett was elected to the Carnegie board of trustees in 1971. After serving several years on the nominating committee, including a stint as its chairman, Hewlett was elected chairman of the board, a position he held from 1980 to 1986.

Besides having a lifelong interest in science, Hewlett was a well-known philanthro-

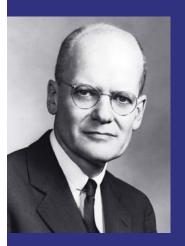
pist who advanced a variety of causes, setting a new standard for Carnegie giving during his tenure. His unprecedented generosity to Carnegie began in 1983, when he established a 10-year lead trust that resulted in \$1 million each year thereafter for Carnegie science.

Over the years he became a champion of the Magellan telescope project. In 1989 he posed a \$5 million challenge to the board of trustees to build the Magellan telescopes, renew the institution's scientific infrastructure, and expand the endowment. The challenge was successfully met, with the rest of the trustees donating more than \$10 million in less than five years.

Hewlett was an exceptionally modest person and insisted on anonymity. When members of the board and the entire Observatories staff asked for permission to name the first Magellan telescope the Hewlett telescope, he declined the offer with a plucky "nice try."

Until his death in 2001, Hewlett made anonymous gifts to Carnegie totaling \$18 million. Carnegie is deeply indebted to William Hewlett for his 16 years of active leadership, his unassuming style, and his unsurpassed generosity. The Hewlett family was appropriately awarded the Andrew Carnegie Medal of Philanthropy in 2005 for exceptional philanthropic generosity and stewardship.

CARYL P. HASKINS



A man who sought "to touch the scientific revolution . . . to generous social purpose." Caryl Parker Haskins had a life mission to promote the importance of scientific research, particularly through his half-century affiliation with the Carnegie Institution. In 1949 the board of trustees elected Haskins. a biophysicist who founded Haskins Laboratories, to the Carnegie board, where he served as a leader on the executive committee for seven years. Then in 1956 the board appointed him to

the Carnegie presidency, succeeding Vannevar Bush. After 15 years at that post, Haskins continued to serve as a board member, first on the executive and nominating committees and later as trustee emeritus until his death in 2001.

When Haskins stepped down from the Carnegie presidency, the Washington Post characterized him as a renaissance man, with a "vast comprehensive knowledge across the whole spectrum of science." Over the years, Haskins worked tirelessly to promote the philosophy of the institution; in his words to "search for scientific truth wherever it may lie, without primary consideration of its use in any practical sphere." His generosity was expansive.

Understanding that scientific endeavor requires substantial, sustained financial support, he and his wife, Edna, became two of the most generous donors in the institution's history, contributing more than \$15 million during their lifetimes and through their estate. Carnegie is indebted to the vision, loyalty, and philanthropy of this great friend.

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\$100,000 TO \$1 MILLION

National Oceanic and Atmospheric Administration Space Telescope Science Institute U.S. Office of Naval Research

Other

\$100,000 TO \$1 MILLION

Institute of Earth Sciences, Academia Sinica International Human Frontier Science Program

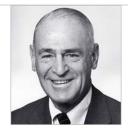
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★ Joseph Gall



Carnegie Institution

★ Wesley Huntress, Jr.



★ Ho-kwang Mao



* Stephen Shectman



* Barry Madore



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HONORS

Former Carnegie president and current trustee Maxine Singer was named the winner of the 2004 AAAS Philip Hauge Abelson Prize.

Trustee emeritus Charles Townes received the Templeton Prize for advocating the "convergence of science and religion."

Senior trustee **Sidney J. Weinberg, Jr.,** was elected a fellow of the American Academy of Arts and Sciences.

Embryology Staff member Joseph Gall received the Elsevier-SDB Lifetime Achievement Award from the Society for Developmental Biology in 2004.

Geophysical Laboratory Geophysical Laboratory director Wesley Huntress, Jr., was made an associate member of the Royal Astronomical Society in February 2005 and in May was awarded an honorary doctorate at Brown University.

Ho-kwang (Dave) Mao won the Mineralogical Society of America's Roebling Medal for 2005 and the 2005 Gregori Aminoff Prize in Crystallography "for pioneering research of materials at ultrahigh pressures and temperatures."

Observatories

Staff astronomer **Stephen Shectman** won the 2005 American Astronomical Society's Weber Prize for his contributions to astronomical instrumentation.

Senior research associate Barry Madore received a Group Achievement Award from NASA administrator Sean O'Keefe for his role on the Galaxy Evolution Explorer.

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Vera Rubin 🖈



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Hatim A. Tyabji 🖈



Alex Bortvin *



Steven Farber 🖈



Seung Rhee *



Dan Kelson 🖈

Plant Biology

Director **Chris Somerville** gave the 2004 Mendel Lecture at the Genetics Society in November. He was also elected a fellow of the AAAS in 2004.

Terrestrial Magnetism

Department director **Sean Solomon** was awarded the American Geophysical Union's 2005 Harry H. Hess Medal for his "outstanding and influential scientific achievements in planetary science, seismology, and marine tectonics." He was also awarded NASA's Public Service Medal in 2004 for his role in the development of the Solid Earth Science Program.

Senior Fellow **Vera Rubin** was awarded an honorary Doctor of Science degree by Princeton University in May 2005.

TRANSITIONS

Chairman of London-based Botts & Company **John C. Botts** was elected to the Carnegie board of trustees in December 2004. Trustees **Freeman A. Hrabowski III** and **Hatim A. Tyabji** stepped down as board members this past year.

Two new staff members, **Alex Bortvin** and **Steven Farber**, joined the Department of Embryology in 2004

Former staff associate **Seung Rhee** was appointed staff member at Plant Biology and **Dan Kelson** was appointed staff associate at the Observatories.



EMBRYOLOGY

Deciphering the Complexity of Cellular, Developmental, and Genetic Biology



Cracking the Code in Cell Communication

From the first spark of conception, cells talk to each other to ensure that tissue development stays on course and diseases such as cancer are kept at bay. Scientists in the Chen-Ming Fan lab at the Department of Embryology recently found an entirely new way this communication works. Their discovery could boost the understanding of how stem cells renew themselves and how cancer forms. It has also received enormous attention from the biological community because it calls into question how many cell communication pathways there are and how distinctive they may be.

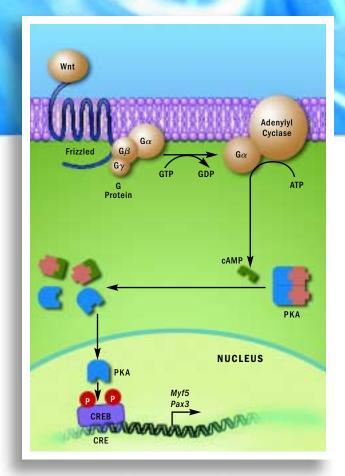
Tissue development involves communication among cells by way of complex molecular relays. A molecule sent from one cell interacts with a surface receptor on a second cell. That receptor relays information to a molecule inside the target cell, which passes the information on to yet another molecule (and so on) until the information gets to the nucleus, where a gene is turned on that will tell the cell what tissue to become—bone, muscle, brain, etc. Remarkably, researchers have identified only seven or eight "signaling pathways" that control tissue development in *all* bilateral animals. And until recently, the pathways were thought to be distinct.

Predoctoral associate Alice Chen, with staff member Chen-Ming Fan and colleagues, discovered an entirely new signaling pathway that appears to be a merger of parts of two other pathways that were believed to be completely independent.

Using skeletal muscles along the backs of embryonic mice, the researchers studied a family of proteins in a pathway called Wnt. The Wnt pathway is important to early embryonic development, stem cell renewal, and tumor growth. The Wnt protein is a ligand—a molecule that binds to a receptor at the surface of a target cell and initiates the relays inside that cell. The team explored the molecules inside the target cell that are involved in turning on the muscle-making genes.

The scientists performed a variety of tests, including a novel technique of infecting mouse embryos with defective forms of two molecules to see how development was affected and to verify which molecules were at work. The researchers found a well-known gene transcription factor—a protein in the nucleus, which begins the process of turning genes on—called CREB near the end of the Wnt pathway. They were surprised because CREB is typically classified in an entirely different signaling chain. They were then able to identify other molecules in the progression, which also turned out to be typically associated with CREB. One of those is a catalyst outside the nucleus called adenylyl cyclase. Another is the molecule PKA, which enters the nucleus and prompts CREB into action.

The discovery that Wnt initiated a cascade that ended with CREB was a surprise to the researchers and the bio-



A chain reaction of molecules turns genes on inside the nucleus of a cell. Members of the Fan lab discovered a previously unknown signaling pathway that begins at the surface of the cell with the Wnt protein. It binds to a receptor and initiates a molecular relay inside the cell. The researchers were surprised to find that CREB, which is a transcription factor that begins to activate a gene, was part of the chain reaction initiated by Wnt.

IMAGE COURTESY NATURE PUBLISHING GROUP.

logical community. The Fan lab will be further examining how this newly discovered pathway affects stem cells in muscle-cell regeneration in the adult.

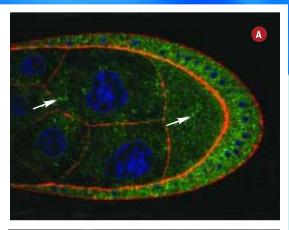
A Genetic Traffic Cop Directs Protein and RNA

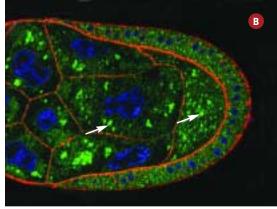
Every cell has a traffic system that would astound the most accomplished city planner. RNA and proteins crowd the streets of these microscopic metropolises, rushing to work at particular locations within the cell. Much like human travelers, these biochemical commuters need signals to help them navigate efficiently. James Wilhelm of Carnegie's Department of Embryology has discovered a gene that helps direct traffic in the eggs of the fruit fly, *Drosophila melanogaster*. More importantly, this gene may provide the first known connection between two very different cellular traffic patterns.

Wilhelm and his collaborators found that the gene, which they named *trailer hitch* (*tral*), is required to move some key developmental proteins. Their results also suggest that *tral* helps move messenger RNAs—molecules that carry genetic messages from DNA to the cell's protein factories. Until now, scientists believed that these two processes were completely independent.

The movement of proteins to the cell surface depends largely on two protein-processing structures, the endoplasmic reticulum (ER) and the Golgi apparatus, which combine to make a convoluted network of membranes

Embryology, continued





and channels. Proteins shuttle between these two structures and through the entire cell in small membrane sacs. But in fruit fly eggs with a mutant *tral* gene, this process doesn't quite work as it should: the ER exit sites—where traffic leaves for the Golgi—become muddled by large lumps of mismanaged proteins.

One of the proteins trapped in these lumps, called Gurken, normally helps distinguish the top side from the bottom as the egg develops into an embryo. With the Gurken proteins tied up in these lumps a proper top-to-bottom pattern is never established, and the embryo dies early.

Inside the cell, proteins shuttle through a convoluted network of membranes and channels, including the endoplasmic reticulum (ER) and the Golgi apparatus. But in *tral* mutants, the sites where traffic leaves the ER for the Golgi become muddled by large lumps of mismanaged proteins. These ER exit sites, stained green and marked by arrows, are abnormally large in mutant egg chambers (B) compared with the wild, or normal, chambers (A).

Wilhelm's results also suggest *tral* mutants have trouble moving at least one other key developmental protein, a growth factor called "yolkless," from the ER exit sites. Yolkless proteins are normally spread evenly throughout the cell, where they help bring yolk nutrients into the egg. But in *tral* mutants, yolkless proteins collect in lumps much like the Gurken lumps.

Wilhelm's team sequenced *tral* and found that it bears a striking resemblance to genes that code for RNA-processing proteins. The surprised researchers explored the possibility of a functional link between *tral* and RNA, and found that *tral*'s protein forms part of an RNA/protein complex that helps process and shuttle messenger RNAs throughout the cell.

By examining *tral* in fruit fly egg cells, Wilhelm and his collaborators have established the first link between protein shuttling and messenger RNA processing. Once believed to be separate phenomena, it now looks like these two freeways share at least one interchange.

GEOPHYSICAL LABORATORY

Probing Planet Interiors, Origins, and Extreme States of Matter

Star Trek Technology Comes Alive

The Star Trek crew in the popular TV show of yesteryear used a lightweight device called a tricorder to detect the presence of life on other worlds, as well as pathogens and contaminants that could harm the humans or their craft. Now Jake Maule, Andrew Steele, and the MASSE team at the Geophysical Laboratory (GL) have successfully fieldtested a precursor to the tricorder that they, along with Charles River Laboratories and the LOCAD group at Marshall Space Flight Center, have been developing over the past few years. The device, frequently referred to as a lab-on-a-chip, will be permanently installed on the International Space Station beginning in 2006 to identify microbes hazardous to astronaut health. A future adaptation of the instrument is slotted to fly the European Space Agency's ExoMars mission to the Red Planet in 2013 to search for evidence of life.

In addition to its handy size, the lab-on-a-chip cuts sample analysis time from about two to three days in a typical lab to some 10 minutes. Samples are also assessed in the field immediately upon collection. A researcher prepares a sample in an aqueous solution and introduces it into a small plastic cartridge, which slides into a slot of the tiny lab. The lab unit incubates the sample in the cartridge with a chemical preparation that turns yellow in the presence of microorganisms. The intensity of the yellow color is proportional to the number of microbes in the sample.

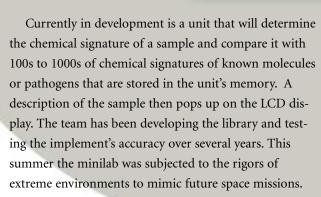
A fully suited astronaut uses the handheld detection device during a training session at Meteor Crater in Arizona. On the International Space Station the unit will be able to detect microbes that may be hazardous to crew health. In the future, an advanced version of the instrument will be able to screen thousands of molecules to monitor astronaut health and the environment, and to detect evidence of life.



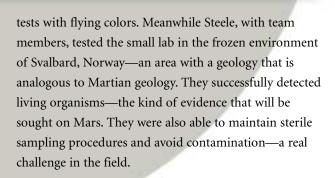
Geophysical Laboratory, continued

Jake Maule, project scientist for the handheld lab-on-a-chip, tests the device on a NASA KC-135 aircraft during a parabolic microgravity flight over the Gulf of Mexico. Beginning in 2006, the minilab will remain on the International Space Station permanently to help the crew identify microorganisms that may be hazardous to their health or cause corrosion of panels, wires, and other components.

IMAGE COURTESY JAKE MAULE.

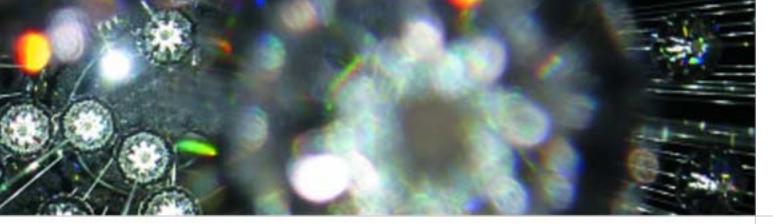


Jake Maule joined a NASA Desert Research and Technology Studies (RATS) team at Meteor Crater in Arizona to see how the device performed in heat and dust, and to train fully suited astronauts in the use of the system. He, Charles River's Norm Wainwright, and GL staff member Marilyn Fogel also took the minilab aloft in a NASA KC-135 aircraft to see how it worked under conditions of microgravity (0g), lunar gravity (0.16g), and Martian gravity (0.38g). The minilab passed the



Meteorites—Historians of the Solar System

Scientists are one step closer to understanding how our solar system formed by studying the most primitive objects around—carbonaceous chondrite meteorites. They are emissaries from a long-gone era in the earliest



solar system and contain clues, in the form of their carbon, which can reveal the temperatures, pressures, and other chemical processing that occurred as the interstellar medium coalesced into the solar system billions of years ago. A challenge to understanding these meteorites, however, has been the establishment of the chemical signatures of specific reactions that altered the parent body, such as an asteroid, and meteorite over time. The Geophysical Laboratory's George Cody and colleague Conel Alexander of the Department of Terrestrial Magnetism are the first to decipher and compare the chemical constituents of four meteorites from distinct groups and relate these chemical differences to their processing histories. The evidence suggests that their organic matter shares a specific reaction pathway—important information for piecing together what happened in the dark reaches of time.

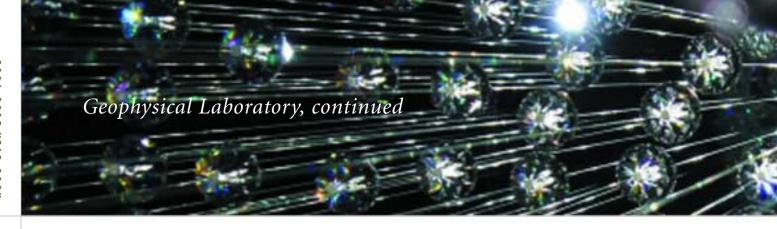
More than 70% of the organic matter in carbonaceous

chondrites is insoluble. Insoluble organic matter (IOM) is difficult to break down and analyze by standard molecular methods. But Cody and Alexander have overcome this hurdle using solid-state nuclear magnetic resonance (NMR) spectroscopy, which reveals molecular information when certain atomic nuclei, aligned by an enormous magnetic field and irradiated with radio-frequency pulses, resonate with characteristic frequencies. The researchers undertook a painstaking analysis of samples from four meteorites—EET92042 (CR group), Orgueil (CI group), Murchison (CM group), and Tagish Lake (a unique group). With a custom-designed procedure developed by Terrestrial Magnetism's Fouad Tera, they extracted the IOM and used a protocol including eight different ¹H and ¹³C NMR measurements to verify the hydrogen and carbon molecular environments.

The scientists found remarkable variation in the chemical composition of IOM across the meteorite



The carbonaceous chondrite meteorite Allende (near left) exhibits the dark fusion crust formed during atmospheric heating. The mottled white and light gray interior is pristine meteorite, with various mineral phases and very little extraterrestrial organic carbon. The vial contains about 400 milligrams of extracted, pure insoluble organic matter from a carbonaceous chondrite. It records history from before the formation of the solar system.



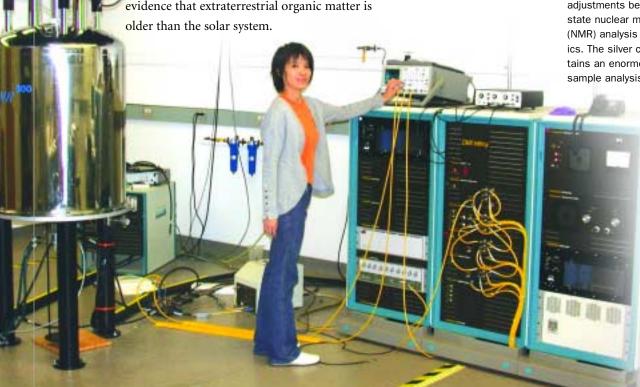
groups. The proportion of aromatic carbon increased significantly from the CR to Tagish Lake, and there was a parallel increase in the abundances of tiny nanodiamonds, vestiges of ancient stars. With multiple NMR experiments, the researchers showed that the increase in aromatic carbon was due to a loss of other forms of carbon—crucial evidence for a low-temperature, chemical-oxidation reaction in the meteorite parent body. They suspect the oxidant is hydrogen peroxide, a likely component of interstellar ices. It appears that the CR meteorites contain the most primitive organic matter. The material is very complex; rich in hydrogen, oxygen, and

is very complex; rich in hydrogen, oxygen, and nitrogen that must have formed from small molecules synthesized in the interstellar medium—evidence that extraterrestrial organic matter is older than the solar system.

Nurture Beats Nature in Diamond Making

A team at the Geophysical Laboratory (GL) is surpassing Mother Nature by breaking speed, size, and strength records to lead the world in diamond making. The team, led by research scientist Chih-Shiue Yan and staff member Russell Hemley, has produced 10-carat, half-inchthick, single-crystal diamonds at a rate of 100 microme-

Hikaru Yabuta, a new Geophysical Laboratory postdoctoral fellow, works with George Cody and Conel Alexander. Here she is making adjustments before starting solid-state nuclear magnetic resonance (NMR) analysis of meteoritic organics. The silver cylinder at left contains an enormous magnet for sample analysis.





tion (CVD) process. It has also made colorless, singlecrystal diamonds that are transparent from the ultraviolet to infrared wavelengths, and it has fabricated new shapes from blocks of the CVD single crystals.

The 10-carat diamond is about five times the size of commercially available diamonds produced by the conventional methods, typically the high-pressure/hightemperature (HPHT) technique. Although the ultimate goal is to produce extremely large diamonds for instrumentation to maintain GL's leadership in high-pressure research, the new breakthroughs have broad applications that could include a new generation of semiconductors.

The team's CVD process begins with a seed diamond placed in a specially designed chamber. The seed is subjected to a gas mixture consisting mainly of methane and hydrogen and then bombarded with intense microwaves to make charged particles, or plasma. A carbon "rain" falls on the seed, and the carbon atoms arrange themselves in the proper crystalline structure, resulting in the growth of the diamond. The scientists can also subject the diamonds to high temperatures and pressures, hardening the crystals and further improving the clarity.

Large, transparent, and high-purity diamonds are especially valuable. These characteristics are particularly challenging and costly to produce with traditional methods. The Carnegie team has overcome these obstacles with the aim of revolutionizing diamond making. The highest growth rate reached thus far is in excess of 300 micrometers per hour. The goal is to grow diamonds as large as 100 carats.



This colorless diamond (top) was cut from a 1-carat block created by the Geophysical Laboratory's diamond-making team using its unique chemical vapor deposition (CVD) process.

This ¹/₂-inch, 5-carat diamond (bottom) came from a 10-carat block produced by the Carnegie CVD process. It is laser cut, inscribed, and partly polished.

IMAGES COURTESY CHIH-SHIUE YAN AND RUSSELL HEMLEY.

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GLOBAL ECOLOGY

Exploring Ecosystems from the Smallest to the Largest Scale



California Climate: Major Impacts on the Horizon

Greenhouse-gas emissions will have major impacts on California's future, states a study in which Christopher Field participated. Field, Department of Global Ecology director, was part of a group of leading scientists from major institutions that investigated greenhouse-gas emissions in California, climate change, and the consequences on the agriculture and economy of the Golden State.

Using results from two of the latest-generation climate models, the team was the first to look at a broad range of impacts for a particular region and assess the sensitivity of the impacts to the future pattern of greenhouse-gas emissions at the global scale. The study showed that more frequent heat waves and dramatically reduced Sierra snowpack are in California's future without aggressive near-term action to minimize greenhouse-gas emissions.

The amount of climate change in the state and the severity of its impacts strongly depend on the level of emissions of heat-trapping gases, such as carbon dioxide. Stanford/Carnegie Ph.D. students Elsa Cleland, Claire Lunch, and Kim Nicholas Cahill participated in the study, which compared an expected future climate with humans heavily using traditional fossil energy (the

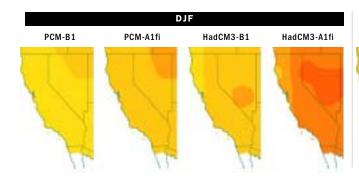
source of most of these heat-trapping gases) with a future climate in which people primarily use energy sources that do not emit heat-trapping gases. The results showed that both scenarios result in significant climate changes over the coming decades; but the amount of climate change could be cut by half, or more, if emissions were dramatically reduced.

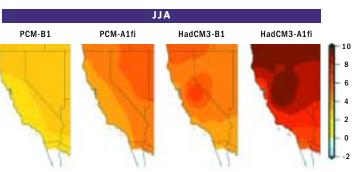
All of the model simulations showed increased temperatures by midcentury. Even with lower emissions, heat waves, extreme heat, and heat-related human mortality in Los Angeles could double to quadruple by century's end. The warming could be great enough for widespread impacts on agriculture.

Forest Destruction in Brazil Is Twice That of Previous Estimates

Until now it has been almost impossible to detect how much area is logged selectively under the forest canopy in Brazil or elsewhere. Global Ecology staff member Greg Asner led a new large-scale, high-resolution satellite study, which showed that when selective logging is taken into account, forest degradation in the Brazilian Amazon has been underestimated by half. The first-of-its-kind study also showed that there are far-reaching ecological impacts for the region and beyond.







The scientists used two different models-the low-sensitivity Department of Energy Parallel Climate Model (PCM) and the medium-sensitivity U.K. Met Office Hadley Centre Climate Model 3 (HadCM3)—to project future temperatures in California under lower (B1) and higher (A1fi) greenhouse-gas emission scenarios. The left series of images shows what the two models predict for winter temperatures with lower and higher emissions for the years 2070 to 2099. Depending on the model, summer temperatures at the end of the century (right) with higher emissions could rise by 8°F or 15°F, with increased warming in the north and northeastern parts of the state. As predicted by the two models, reducing emissions could result in temperatures increased by 4°F or 7°F.

IMAGE REPRINTED WITH PERMISSION FROM PNAS 110 (NO. 34), 12422-12427.

Selective logging is a technique whereby loggers extract specific types of commercially valuable trees one by one from the fragile rain forest, while the forest canopy covers their tracks. Although it is relatively straightforward to use satellite data to estimate large-scale deforestation from clear-cutting, Asner's group is the first to detect both the extent of selective logging in the Amazon and its impacts on the structure of the forest.

New remote sensing techniques, developed in Asner's lab, are used for projects ranging from quantifying forest disturbance to identifying the chemical composition of forest canopies and undergrowth. Over five years of field-based studies, the scientists discovered that, annually, selective logging disturbs an area about the size of Connecticut (between 4,685 and 7,973 square miles) over the five states that account for 90% of all deforestation in the Brazilian Amazon. The destruction adversely impacts many plants and animals and increases erosion and fires. Additionally, up to 25% more carbon dioxide is released to the atmosphere each year, above that which would be



The red areas (hot spots) show where the Asner-led team found selective logging in Brazil.

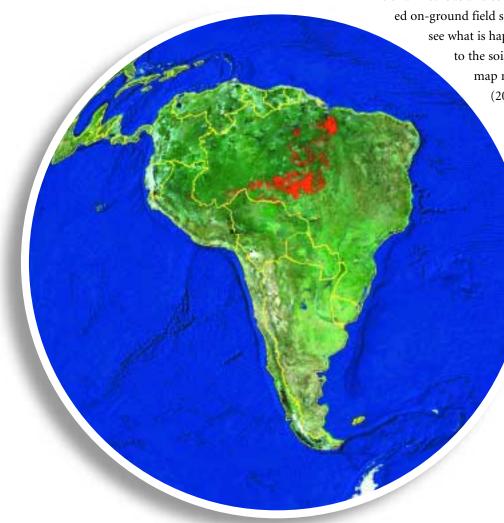
IMAGE COURTESY THE CARNEGIE INSTITUTION AND GOOGLE EARTH.

released by clear-cutting alone.

Along with technicians David Knapp, Paulo Oliveira, and Eben Broadbent, Asner developed the Carnegie Landsat Analysis System (CLAS) to penetrate the canopy by analyzing satellite imagery with advanced computational methods and corroborating the results with selected on-ground field studies. The researchers can now see what is happening from the top of the forest to the soil. The group is now using CLAS to map more than 7.7 million square miles (20 million km²) of forest.

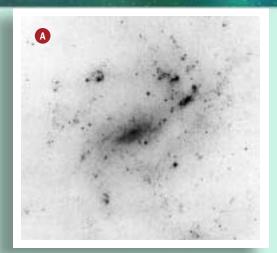
The researchers are hopeful that

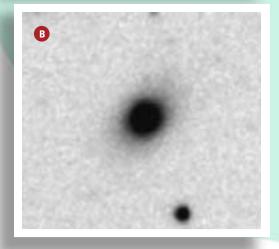
The researchers are hopeful that their new techniques can be expanded to monitor logging in other tropical forest countries. One goal is to provide the satellite results to government officials in Brazil to help in enforcement of the laws that prohibit illegal logging.



OBSERVATORIES

Investigating the Birth, Structure, and Fate of the Universe





The Ho-led team found "miniquasars" in unlikely places: NGC 4395, a very late-type spiral galaxy with no bulge (A), and POX 52, a dwarf elliptical galaxy (B). Both of these objects, along with many others like them, were found to contain black holes in the previously unknown mass range of 104 to 106 Suns.

"Tiny" Black Holes Discovered in "Tiny" Galaxies

Once thought a rarity, black holes—those extremely dense objects with a gravitational force so strong that not even light can escape—turn out to be quite common. In fact, supermassive black holes exist at the center of most large galaxies. Observatories astronomer Luis Ho, with Harvard graduate student Jenny Greene and University of California, Irvine, associate Aaron Barth, has discovered an entirely new population of these powerhouses— "tiny" black holes that reside in "tiny" galaxies. This discovery may help decipher the origin of their heavier counterparts. Ho thinks that small black holes were more common in the past and could be the "seeds" of their supermassive cousins.

Supermassive black holes have masses that range from millions to billions of Suns. Astronomers believe that somehow their formation and growth are integral to galaxy life cycles, particularly the central concentration of stars known as the bulge. Our Milky Way, a common spiral with a modest bulge, harbors a 3-million-solarmass black hole. Hefty ellipticals and early-type spiral galaxies also have bulges, but late-type spirals and tiny dwarf galaxies do not. Every bulge has a black hole, and the mass of the black hole is proportional to the size of the bulge.

Observatories, continued

Ho asked: Do black holes require a bulge? Do galaxies without bulges—the smaller systems that make up the bulk of the galactic population—truly lack black holes? If black holes do reside in small, bulgeless galaxies, the galaxies would probably have masses from a thousand to a million Suns. These black holes are likely to be quite rare today, and current technology cannot detect their dynamical signature except among a handful of our nearest neighbors. People have looked, but to no avail.

The Ho-led team overcame this obstacle. They reasoned that small galaxies, with small black holes, should glow as miniquasars, signposts of the tremendous energy released as material falls into these gravitational pits. They combed through mountains of data from nearby galaxies and were the first to find the elusive signal indicating that small black holes reside in this bulgeless galaxy population.

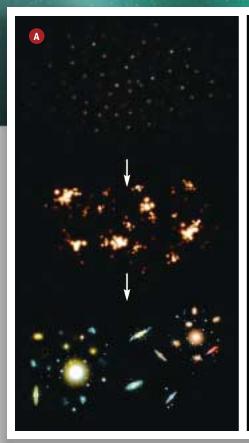
Ho believes that small black holes could be seeds of supermassive black holes that could have coalesced through the hierarchical merging of galaxies over time. In the process, they would release tiny ripples of space-time—gravity waves—that physicists hope to detect in the coming decades.

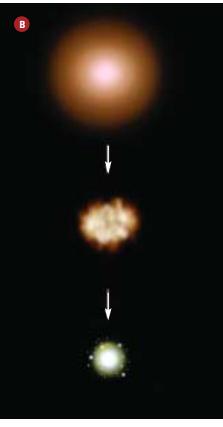
Galaxy Formation: Top Down or Bottom Up?

Get out of town on a clear night and you can see into the heart of the Milky Way; millions of distant stars blend into a luminous band, while the closer stars form familiar constellations that march across the sky. The origin of large galaxies like the Milky Way is one of the great unsolved mysteries of astrophysics. One outstanding question is whether galaxies form "bottom up" from the gradual assembly of smaller building blocks, or "top down" from the collapse of large gas clouds that fragment into smaller star-forming clusters. Carnegie Observatories staff member Patrick McCarthy and his colleagues are bringing this conundrum into clearer focus.

The bottom-up model has prevailed over the past decade because it offers a good explanation for the distribution of galaxies. This scheme suggests that the most massive objects should be the youngest, because their assembly would have taken the most time. But astronomers have found that the most massive galaxies consist almost exclusively of old stars. It could be that the individual building blocks are old, while the galaxies themselves are young. To sort out the issue, scientists need to peer back in time to when massive galaxies were first formed.

While simple in concept, this effort has proven challenging in practice—the galaxies in question are faint, and most of their radiation has shifted to lower-energy, non-





In the "bottom-up" scenario (A), galaxies form via the clustering of smaller building blocks. The smallest galaxies form first, and large galaxies build up slowly as smaller galaxies merge together.

In the "top-down" model (B), galaxies form from the rapid collapse of a single cloud of gas. As the cloud collapses it breaks into fragments, forming star clusters and smaller groups of a few stars.

visible infrared light. McCarthy's team surmounted this challenge with an ambitious infrared study using the du Pont telescope at Carnegie's Las Campanas Observatory. Their results were surprising—the young universe contained 50 to 100 times as many massive galaxies as the bottom-up model would predict. If these massive galaxies existed when the universe was relatively young, then they probably did not form from the gradual assembly of smaller building blocks.

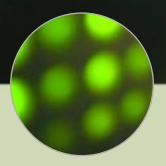
Directly measuring the age of galaxies can help settle the matter. But determining a galaxy's age, specifically that of its stars, is not easy. Conventional wisdom says that a galaxy's hottest, most massive stars will die first, leaving cooler, less massive stars as the galaxy matures. It should therefore be possible to estimate a galaxy's age by measuring the temperatures of its hottest stars. McCarthy and his team found many distant, massive galaxies composed of stars hotter than the Sun. These galaxies are also old, having formed only 1.5 to 3.5 billion years after the birth of the universe.

The formation of smaller galaxies is still best explained by the bottom-up model, but McCarthy's work provides strong evidence that the most massive stellar systems formed early, and from the top down.

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PLANT BIOLOGY

Characterizing the Genes of Plant Growth and Development



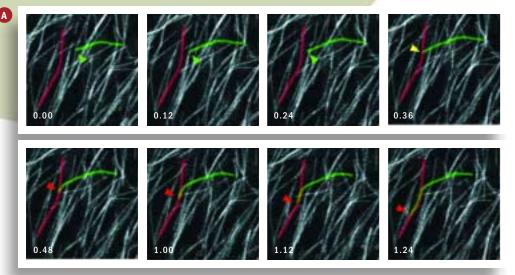
A Glimpse at Cellular Construction Crews

Much like buildings, plant cells have rigid walls to define their shape. These walls take many forms, from spiky, thornlike trichomes that fend off hungry bugs, to sausage-shaped guard cells that regulate the plant's breathing pores. David Ehrhardt and colleagues at Carnegie's Department of Plant Biology and Stanford University use groundbreaking imaging techniques to observe the proteins that create this array of shapes. They are the first to watch these molecular construction crews at work during cell growth. This important basic research has already revealed plants to be as dynamic and complex as their animal counterparts.

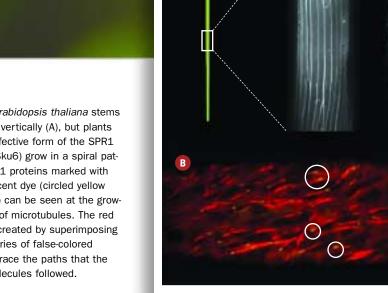
These proteins help plant cells work around a unique problem: unlike animal cells, plant cells have rigid walls and cannot easily change shape. Once they are in place, plant cells can only grow outward. To get it right the first time, plant cells rely on scaffolding made of microtubules—stiff rods made from a protein called tubulin. Microtubules constantly move and change shape as the cell wall pushes outward, but until now scientists knew very little about how the cell controls this process.

To get a closer look, Ehrhardt and collaborators fused

A growing microtubule (green) "bundles" (A) with a second microtubule (red) as it advances. A drawing of microtubules "treadmilling" and "bundling" is shown in B (opposite). As new tubulin molecules (green) attach to the growing end (top), they are also lost from the trailing end (bottom). The loss of tubulin from the trailing end is especially important because it erases old, less organized microtubule structures, allowing more ordered structures to replace them. Researchers believe a specialized protein (orange dots) helps the microtubules bundle together.



Sku6



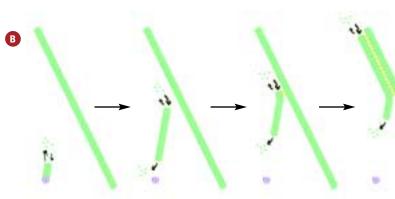
Normal Arabidopsis thaliana stems (wt) grow vertically (A), but plants with a defective form of the SPR1 protein (Sku6) grow in a spiral pattern. SPR1 proteins marked with a fluorescent dye (circled yellow dots in B) can be seen at the growing ends of microtubules. The red streaks, created by superimposing a time series of false-colored images, trace the paths that the SPR1 molecules followed.

a tubulin gene from the model plant Arabidopsis thaliana with a fluorescent protein gene to express fluorescent tubulin protein. Using a specialized confocal microscope, they watched these proteins reorganize themselves in living cells. Ehrhardt found that microtubules move just under the surface of the cell, shortening at one end while lengthening at the other end. They do this one tubulin molecule at a time, in a process the researchers call treadmilling.

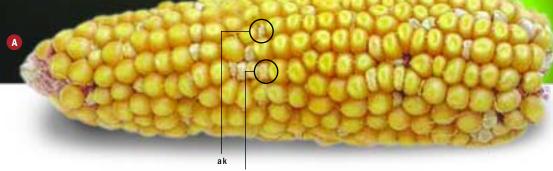
Treadmilling microtubules inevitably bump into stationary microtubules as they explore new territory in the cell. Instead of shoving past these obstacles, the growing fibers will often link up with the older ones and follow the same path. Ehrhardt believes this process, called bundling, helps the cell forge a strong, highly organized lattice from a random patchwork of microtubules.

Ehrhardt's lab is searching for the molecules that guide treadmilling and bundling, and they have found

> a possible candidate: a protein called SPR1 that attaches to the growing end of treadmilling microtubules. Cells with nonfunctional SPR1 proteins grow in an abnormal spiral pattern, as does the entire plant. Although the exact function of the protein remains unknown, the spiraling defect suggests that SPR1 is a major player in either configuring microtubules or control-



Plant Biology, continued



ling their function.

Ehrhardt's lab plans to dig deeper into the engineering of plant cells. For example, they want to find other proteins that help guide treadmilling and bundling, and determine whether and how microtubules guide other construction processes in the cell. Recent work suggests that microtubules might directly guide construction of the cell wall. By snapping real-time imagery of tubulin molecules at work, Ehrhardt and his colleagues are helping to illuminate the structure and organization of plant cells.

Navigating a Genetic "Maize"

Plants, like animals, depend on specific genes to choreograph the dance of early development. But unlike animals, plants have two distinct generations, one with a single and one with a doubled set of chromosomes. Researchers in Matt Evans's lab at Carnegie's Department of Plant Biology are the first to locate and clone a gene in maize that plays a big role in both generations. The work may allow breeders to produce agriculturally useful varieties of maize, an economically significant crop, more quickly.

The gene is known to affect the embryo sac, the female version of the single-chromosome generation. When the sac combines with a pollen grain—the male version—the two form a seed with a double set of chromosomes. This fertilized seed produces the double-chromosome plant

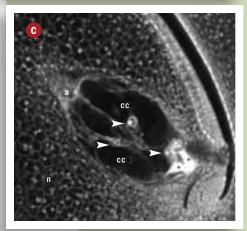
In ears of maize with a mutant *ig1* gene (A), many kernels do not grow to full size (mn), or completely abort early in development (ak). The embryo sac in *ig1* mutant maize (C) contains extra cells and malformed structures as compared with the wild-type embryo sac (B).

from which the next generation will arise.

Though Evans's group is not yet sure exactly what purpose the gene, called *ig1*, serves in the developing embryo sac, they do know what happens when the gene malfunctions. Embryo sacs with a mutated form of *ig1* often produce defective seeds riddled with abnormalities, such as a shrunken endosperm (the starchy capsule that feeds the growing embryo) and multiple embryos. The embryo sacs can produce too many cells, some with too many nuclei crammed inside.

Other researchers have documented the effects of *ig1* mutations, but Evans and his colleagues are the first to determine exactly where in the maize genome the *ig1* gene actually resides. To find the locus among tens of thousands of possibilities, the researchers relied on a close cousin of maize: rice. Since maize and rice share much of their genetic order, and the entire genome sequence of rice is known, Evans's group used rice as a genetic roadmap to find *ig1* in maize.





Evans and his colleagues are also the first to determine that ig1 affects the double-chromosome generation as well as the single-chromosome generation. As it turns out, the gene's sequence is similar to a gene called AS2 from Arabidopsis thaliana, a plant commonly used in genetic studies. AS2 controls aspects of double-chromosome generation development in Arabidopsis, and it appears ig1 serves a similar purpose in maize.

Evans found evidence to support this idea in one of two distinct ig1 mutations, called ig1-mum. Plants with this mutant have misshapen leaves, much like Arabidopsis plants with mutated AS2 genes. The ig1-mum variant also disrupts other vital developmental genes, just as mutant as2 protein does in Arabidopsis. The mutation also causes an overproliferation of leaf cells, much like the effect it has on the embryo sac.

Because mutations in ig1 seem to affect both generations, Evans believes there is more regulatory overlap between the phases than was once thought. And by locating the ig1 gene and identifying its mutations, he and his collaborators have opened up a promising new avenue for maize research.

A Tale of Brains over Bran

To the casual observer, brain cells and plant cells might seem a world apart, but they actually have a lot in common. Wolf Frommer and Sakiko Okumoto, of Carnegie's Department of Plant Biology and Stanford University, have designed a way to track a substance called glutamate required by both cell types. In fact, they are the first to measure real-time glutamate changes in single living cells. Their technique holds promise for disease research, since it is suspected that too much glutamate may aggravate conditions like Alzheimer's and Parkinson's diseases.

Glutamate is a mammalian neurotransmitter required for a score of mental processes, from learning and memory to mood and perception. It is also vital for proper growth and chlorophyll production in plants. To study glutamate in both systems, Frommer and Okumoto use a technique called fluorescence resonance energy transfer, or FRET.

FRET detects metabolites such as sugars and amino acids using a "biosensor." Tags made from differently

Plant Biology, continued

colored variants of green fluorescent protein (GFP), one cyan and one yellow, are genetically fused to opposite ends of a protein. When a metabolite such as glutamate binds to this biosensor, it changes the shape of the sensor's backbone, altering the position of the fluorescent tags. When light of a specific wavelength activates the cyan tag, it begins to fluoresce. If the tags are close together, the cyan tag can then trigger the yellow tag to fluoresce.

The tags act like two musical tuning forks with a similar tone. Strike one and it begins to resonate; it can then cause the second to resonate, even if they do not touch.

FRET sensors detect the presence of glutamate by physically changing shape. When glutamate (red sphere) binds to the sensor, it changes from the open, unbound form (left) to the closed, bound form (right). This brings the fluorescent tags (blue and yellow cylinders) at each end of the glutamate-binding protein (green disks) closer together.

Glutamate

Extracellular Space

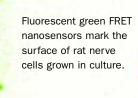
> Plasma Membrane

> > Cvtosol

Instead of sound, FRET tags produce and transfer fluorescent light when they vibrate. Frommer's sensors have a genetic targeting sequence that places them on the cell's outer surface, where the light they produce provides a sensitive, visible readout of glutamate release.

Frommer's lab has also developed FRET sensors to monitor sugars like glucose, the source of metabolic energy for all cells. With these, they study glucose release from liver cells, a process that assures a constant energy supply to the brain and other organs.

The ability to track when, where, and how such chemicals behave can help answer many complicated questions in both animal and plant cell biology, and might one day help find a cure for debilitating diseases. With the methods developed in Frommer's lab, researchers should be able to engineer FRET-tagged markers to monitor other metabolites, expanding the reach of this useful technique.



TERRESTRIAL MAGNETISM

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



Closing In on Other Earths

The ultimate dream of planet hunters is to identify other worlds around nearby stars that potentially harbor life. This race to find life elsewhere in the galaxy has been heating up in recent years, and researchers at the Department of Terrestrial Magnetism (DTM) are leaders in the quest.

First Light Detected from an Extrasolar Planet

Most of the 150 or so known extrasolar planets have been discovered and studied through techniques such as finding the telltale wobble of a star induced by an orbiting planet, or the "blink" of a star as a planet passes in front of it. Using NASA's Spitzer Space Telescope a team of astronomers, including DTM's Sara Seager, have for the first time observed an extrasolar planet through the light it emits in the infrared. This success opens the way to study extrasolar planets' temperatures and compositions.

The planet, HD 209458b, is a massive gaseous world that orbits very close to its parent star and is thus known as a hot Jupiter. Astronomers cannot yet see these planets in the visible part of the spectrum because the light from the star vastly outshines that from the planet. In the infrared, however, the planets show up more brightly and can more easily be detected. HD 209458b was discovered indirectly in 1999 and was later found to transit its staras the planet passes in front of the star during orbit, the star dims. A planet that passes in front of its parent star also passes behind it. Using Spitzer, Seager and colleagues measured the combined infrared light of the planet and the star before the planet went out of sight behind the star. When the planet was out of view, they measured how much energy the star emitted on its own. The difference between those readings told them how much energy the planet gives off (at the measured wavelength). It is equivalent to a scorching 1570°F (1130 K). That temperature is key to refining atmosphere models created to infer the composition and infrared emissions of hot Jupiters.

Earth's Bigger Cousin

DTM's Paul Butler and team announced this summer the discovery of the smallest and most Earth-like extrasolar planet yet detected. The new ability to detect the tiny wobbles in the star from a small planet gives astronomers confidence that they will be able to find even smaller rocky planets at orbital distances more conducive to supporting life. The research was conducted at the Keck Observatory in Hawaii as part of the California and Carnegie Planet Search. The program is surveying the nearest 2,000 Sun-like stars and has found more than two-thirds of the 150 known planets, including the transit planet HD 209458b.

Terrestrial Magnetism, continued





These artist's renderings show what a "hot Jupiter," orbiting close to its parent star, might look like in both the optical and infrared parts of the electromagnetic spectrum. The scene at left represents visible light, where the light of the smaller planet is overpowered by light from the star. In the infrared (right), the hotter star gives off more blue light than red, allowing the planet to be observed with greater clarity.

IMAGE COURTESY NASA/JPL-CALTECH/ R. HURT, SPITZER SCIENCE CENTER.

The newly discovered Earth-cousin orbits the star Gliese 876, located 15 light-years away in the direction of the constellation Aquarius. The scientists believe that the planet may be the first rocky planet ever found orbiting a star similar to the Sun. It is about seven and a half times as massive as Earth, with about twice the radius. At 0.021 astronomical units (AU), or 2 million miles from its parent star, it is much closer to its star

than Mercury is to our Sun, and it makes an orbit in

just under 2 days.

All of the other extrasolar planets discovered to date around Sun-like stars have been more massive than Uranus, an icy giant with about 15 times the mass of Earth. Although there is no direct proof that the new planet is rocky, its low mass would prevent it from retaining a huge gas envelope as Jupiter does. The researchers

believe that its composition is probably like the inner planets of this solar system.

The planet's proximity to the star results in a surface temperature between 400° and 750°F—too hot for liquid water and therefore incompatible for life to develop.

Gliese 876 is an M dwarf. M dwarfs are small red stars with less than half the mass of the Sun. They are the most common type of star in the galaxy. Very few Jupiter-mass planets have been found orbiting M dwarfs, but as measurement precision improves smaller planets have begun to emerge, suggesting a large population of Earth-mass planets. Because these stars are cooler and smaller than the Sun, the orbits on which a planet could sustain liquid water on its surface have periods from days to weeks. Precision Doppler monitoring is already capable of detecting such planets.



This artist's rendering depicts three planets orbiting Gliese 876. The outer planets have masses of 2.5 and 0.8 Jupiter-masses. Jupiter is 318 times more massive than the Earth. The new inner planet (far right, nearest the star) has a mass of 7.5 Earth-masses.

IMAGE COURTESY LYNETTE COOK.

Revamping Earth's Early History

Research by Department of Terrestrial Magnetism's Carnegie Fellow Maud Boyet and staff member Rick Carlson challenges the standard model of the geochemical evolution of the Earth. The work was cited by Science magazine as a runner-up breakthrough of the year for

2005. According to the standard model, the Earth's mantle, the layer between the core and the crust, has been evolving gradually over Earth's 4.5-billion-year history. These DTM geochemists have found, instead, that the mantle separated into chemically distinct layers within 30 million years of the solar system's formation. Their work substantiates DTM director emeritus George Wetherill's theoretical models of early terrestrial planet formation, where collisions between small, rocky planetesimals, bombardment of the growing planets by large bodies, and the energy released from short-lived radioactive elements created deep, churning magma oceans that cooled and crystallized early in the solar system's history.

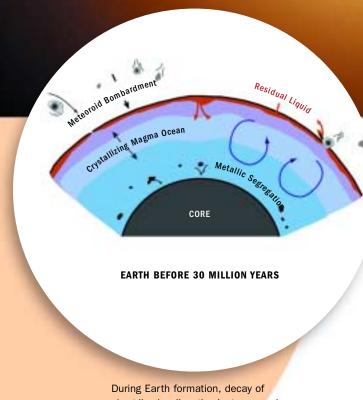
Boyet and Carlson analyzed isotopes contained in rock samples to understand the geochemical history and evolution of the Earth and other bodies in the solar system. Isotopes—atoms of an element with the same num-

Terrestrial Magnetism, continued

ber of protons, but a different number of neutrons—exist naturally in different proportions and can be useful for determining conditions under which rock forms. Radioactive isotopes decay at a predictable rate and can reveal a sample's age and when its chemical composition was established.

Earth formed from the collision and accretion of rocky bodies shortly after solid material began forming in the early solar system 4.567 billion years ago. The chemical composition of these building blocks is preserved today in primitive meteorites called chondrites. In the 1980s, scientists analyzed the ratio of isotopes of the rare Earth element neodymium in chondrites and various terrestrial rocks collected at or near the Earth's surface and found that the samples shared a common composition. Researchers believed that this ratio remained constant from the time the Earth formed. Now, using a new-generation mass spectrometer, Boyet and Carlson found, surprisingly, that the terrestrial samples had an excess of the mass 142 isotope of neodymium (142Nd). 142Nd is the decay product of a now-extinct radioactive isotope of samarium (146Sm). The composition of the part of the Earth that has contributed melts to the surface over time diverged from that of the meteorites' parent bodies within the first 30 million years after solar system formation (less than 1% of the age of the Earth), which was when ¹⁴⁶Sm was decaying into ¹⁴²Nd.

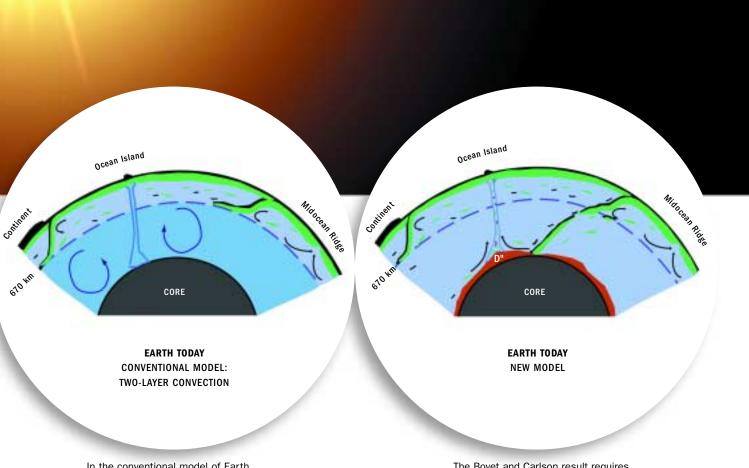
To explain the excess of ¹⁴²Nd found in the terrestrial samples, the scientists conclude that rapid crystallization of Earth's early magma ocean caused the mantle to sepa-



short-lived radioactive isotopes and surface bombardments from large bodies heated Earth's mantle and created a deep magma ocean.

Crystallization of the magma ocean created compositionally distinct layers (blues), while leftover liquid (red) remained just under the primordial crust.

rate into chemically distinct layers, one containing a high ratio of Sm to Nd, similar to that observed today in the mantle source of the volcanism along ocean ridges. The complementary reservoir, with low ¹⁴²Nd abundance, has never been sampled at the surface and hence could now be deeply buried in the so-called D" layer at the very base of the mantle, above the core. This "missing" layer should be rich in the elements uranium, thorium, and potassium, whose long-lived radioactive decay would heat Earth's interior. This hot layer above the core could



In the conventional model of Earth history, the mixing caused by mantle convection erased this early chemical differentiation. The only chemical variation in the mantle is that caused by the formation of the continental crust, leaving the upper mantle (light blue) deficient in those elements concentrated in the crust (black), while most of the mantle is still similar in composition to the chondritic meteorites from which Earth accumulated.

help keep the outer core molten so that circulation of liquid iron can produce Earth's magnetic field and instigate the hot plumes of upwelling mantle material that give rise to volcanically active islands, such as Hawaii.

Because lunar rocks have the same abundance of 142 Nd as the terrestrial samples, the finding also adds to the evidence that the Moon formed from the Earth. Since

The Boyet and Carlson result requires the Earth to have differentiated early, within 30 million years, leaving most of Earth's mantle (light blue) depleted in those elements that prefer melts over crystallizing solids. The chemical complement to the depleted mantle could be small and quite enriched in radioactive elements, such as uranium and thorium; this complementary material may coincide with the seismically observed D" layer, located between the core and the mantle some 2700 km deep.

IMAGES COURTESY MAUD BOYET.

Mars also experienced early melting, as indicated by the chemical and isotopic composition of Martian meteorites, the Boyet and Carlson work now links the Earth, Moon, and Mars and highlights the importance of early events in determining the chemical characteristics of the terrestrial planets.

FIRST LIGHT AND THE CARNEGIE

Teaching the Art of Teaching Science



CASE and First Light Graduate!

This was a milestone year for the Carnegie Academy for Science Education (CASE), a program formed 11 years ago to instruct elementary school teachers from the District of Columbia Public Schools (DCPS) in the art of teaching science and mathematics. The long-term goal at CASE has been to turn much of the effort over to the CASE Mentor Teachers, who have been trained by the Carnegie staff over the years, so as to create a selfsustaining program and build capacity within DCPS. This goal was reached this year when 12 Mentor Teachers from the D.C. schools ran the four-week summer institute under the supervision of the CASE staff. For the first time, the Mentor Teachers organized and taught the highly successful and enjoyable approach to teaching science pioneered by CASE, an approach based on conducting scientific experiments while integrating mathematics and technology in the process.

Because of the school system's increasing emphasis on science in secondary school, the CASE staff is moving on to this level. For 15 years the First Light Saturday science school has offered 15 to 20 third to sixth graders exposure to science through innovative hands-on experiments and field trips. Over the years, the students' regular schools

found that the First Light students were performing better than their peers. This success led principals to seek out CASE for teacher training in higher grades. This year CASE received funding from the D.C. State Education Office to improve teacher quality in middle school mathematics and science by helping teachers from public, charter, and parochial schools learn the unique CASE methods.

As part of this new initiative, CASE ran a two-week summer institute that focused on the field of astrobiology—a multidisciplinary approach to understanding the origins of life in the universe. The group, which included teachers of life sciences, Earth and planetary science, and mathematics, looked at questions that integrate these topics. In addition to learning through participating in experiments, the teachers visited the laboratories of Carnegie's Geophysical Laboratory and Department of Terrestrial Magnetism, whose scientists are affiliated with the NASA Astrobiology Institute. The instructors ended their course by developing lesson plans to implement in their own classrooms.

Drawing on its extensive expertise in molecular biology, the CASE staff also ran a new summer program in biotechnology for high school teachers and students. This course, in cooperation with the new D.C. McKinley Technology High School and the DCPS Office of Career and Technology Education, prepares students to work in biotech fields and teaches instructors how to present the curriculum. The staff is also working with the DCPS Central Office, area postsecondary schools, such as near-by Montgomery College and Catholic University, and

ACADEMY FOR SCIENCE EDUCATION

Washington, D.C., middle school teachers receive training in the art of teaching hands-on science, mathematics, and technology at the Carnegie Academy for Science Education (CASE) 2005 summer session. Former Carnegie president Maxine Singer (left), founder of the program and senior scientific advisor for CASE, attends this session.

2005 marked the first year that the First Light Saturday science school opened its doors to middle school students.

First Light middle school students participate in field trips and collect samples as part of the curriculum.

IMAGES COURTESY TOBY HORN

First Light also graduated to middle school this year. Now every Saturday about 20 sixth through eighth graders from D.C. public and charter schools are immersed in entertaining and instructive laboratory science activities and take field trips throughout the Washington metropolitan area. As CASE and First Light mature, more and more individuals and institutions are becoming exposed to their unique educational techniques. From the very beginning, these programs have sparked curiosity and shown the uninitiated how science touches our lives every day, and how teachers can become classroom scientists along with their students.

local "biotech industries," including the National Institutes of Health and Walter Reed Army

Medical Center, to develop an

advanced technological education

program to help teachers prepare

students for careers in the burgeoning field of biotechnology.





FINANCIAL PROFILE & FINANCIAL STATEMENTS

FINANCIAL PROFILE for the year ending June 30, 2005

READER'S NOTE: In this section, any discussion of spending levels or endowment amounts are 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.

The primary source of support for Carnegie Institution of Washington's activities continues to be its endowment. This reliance has led to an important degree of independence in the research program of the institution. This independence is anticipated to continue as a mainstay of Carnegie's approach to science in the future.

At June 30, 2005, the endowment was valued at over \$635 million and had a total return (net of management fees) of 16.6%. The annualized five-year return for the endowment was 10.5%.

For a number of years, Carnegie's endowment has been allocated among a broad spectrum of asset classes. This includes fixed-income instruments (bonds), equities (stocks), absolute return investments, real estate partnerships, private equity, and natural resources partnerships. The goal of diversifying the endowment into alternative assets is to reduce the volatility inherent in an undiversified portfolio while generating attractive overall performance.

In its private equity allocation, the institution accepts a higher level of risk in exchange for a higher expected return. By entering into real estate partnerships, the institution holds part of its endowment in high-quality commercial real estate, deriving both the possibility of capital appreciation and income in the form of rent from tenants. Along with the oil and gas partnership, this asset class provides an effective hedge against inflation. Finally, through its investments in absolute return partnerships and hedge funds, the institution seeks to achieve long-term returns similar to those of traditional U.S. equities with reduced volatility and risk.

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.

	Target Allocation	Actual Allocation
Common Stock	35.0%	33.6%
Alternative Assets	52.5%	48.8%
Fixed Income and Cash	12.5%	17.6%

The above chart shows the allocation of the institution's endowment among the asset classes it uses as of June 30, 2005.

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. To achieve this objective, it employs a budgeting methodology that provides for:

- averaging the total market value of the endowment for the three most recent fiscal years, and
- developing a budget that spends at a set percentage (spending rate) of this three-year market average.

Since the early 1990s, this budgeted spending rate has been declining in a phased reduction, moving towards an informal goal of a spending rate of 4.5%. For the 2004-2005 fiscal year, the rate was budgeted at 5.10%. While Carnegie has been reducing this budgeted rate by between 5 and 10 basis points a year, there has also been continuing, significant growth in the size of the endowment. The result has been that, for the 2004-2005 fiscal year, the actual spending rate (the ratio of annual spending from the endowment to actual endowment value at the conclusion of the fiscal year in which the spending took place) was 4.29%.



BUDGETED AND ACTUAL SPENDING RATES



Within Carnegie's endowment, there are a number of "Funds" that provide support either in a general way or in a targeted way, with a specific, defined purpose. The largest of these is the Andrew Carnegie Fund, begun with the original gift of \$10 million. Mr. Carnegie later made additional gifts totaling another \$12 million during his lifetime. Together these gifts are now valued at over \$563 million.

PRINCIPAL FUNDS UNDER ACTIVE INVESTMENT MANAGEMENT

(Includes \$635 million of endowment and other assets)

	FY 2005
	* 500 000 000
Andrew Carnegie	\$563,226,808
Mellon Matching	13,642,655
Astronomy Funds	12,133,834
Anonymous	8,830,089
Anonymous Matching	8,104,407
Capital Campaign	9,311,421
Wood	7,027,095
Golden	5,212,774
Science Education Fund	3,214,365
Colburn	2,166,880
McClintock Fund	2,030,893
Bush Bequest	1,580,437
Endowed Fellowships	1,643,670
Starr Fellowship	952,857
Roberts	541,551
Lundmark	397,745
Hollaender	307,675
Forbush	176,965
Hale	149,736
Green Fellowship	146,343
Harkavy	142,842
Endowed Obs positions	130,553
Total	\$641,071,595

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, 2005 and 2004, 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 consideration of internal control over financial reporting as a basis for designing audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of Carnegie's internal control over financial reporting. Accordingly, we express no such opinion. 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, 2005 and 2004, and its changes in net assets and its cash flows for the years then ended, in conformity with accounting principles generally accepted in the United States of America.

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 schedule 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.



November 29, 2005 Washington, D.C.

STATEMENTS OF FINANCIAL POSITION

June 30, 2005 and 2004

	2005	2004
Assets		
Cash and cash equivalents Accrued investment income Contributions receivable, net (note 2) Accounts receivable and other assets Bond proceeds held by trustee (note 6) Investments (notes 3 and 14) Property and equipment, net (notes 4, 5 and 6)	\$186,133 196,512 7,459,804 8,673,414 4,920,242 641,071,595 159,218,202	518,726 99,044 7,155,007 8,425,062 18,209,191 590,769,709 144,813,240
Total assets	\$821,725,902	769,989,979
Liabilities and Net Assets Liabilities: Accounts payable and accrued expenses Deferred revenue (note 5) Broker payable Bonds payable (note 6) Accrued postretirement benefits (note 8)	\$7,173,434 34,914,748 204,718 64,710,315 15,625,000	4,115,909 34,695,018 — 64,670,359 13,670,000
Total liabilities	122,628,215	117,151,286
Net assets (note 9): Unrestricted: Invested in property and equipment, net Held for managed investments Undesignated	66,792,849 524,262,300 32,446,383	63,657,053 491,619,513 32,401,168
Total unrestricted net assets	623,501,532	587,677,734
Temporarily restricted Permanently restricted	36,086,697 39,509,458	25,910,003 39,250,956
Total net assets	699,097,687	652,838,693
Commitments and contingencies (notes 10,11 and 12)		
Total liabilities and net assets	\$821,725,902	769,989,979

See accompanying notes to financial statements.

STATEMENTS OF ACTIVITIES

Years ended June 30, 2005 and 2004

				2005
Revenues and support: External revenue:	Unrestricted	Temporarily Restricted	Permanently Restricted	TOTAL
Grants and contracts Contributions and gifts (note 13) Net losses on disposals of property Other gains (losses)	30,441,132 1,024,221 (15,971) 830,402	6,528,348 — —	258,502 — —	30,441,132 7,811,071 (15,971) 830,402
Net external revenue Investment income, net (note 3) Other (note 9):	32,279,784 68,602,358	6,528,348 7,958,402	258,502 —	39,066,634 76,560,760
Net assets released from restrictions Matching of endowment	4,310,056 —	(4,310,056) —		
Total revenues and other support	105,192,198	10,176,694	258,502	115,627,394
Expenses: Program expenses: Terrestrial Magnetism Observatories Geophysical Laboratory Embryology Plant Biology Global Ecology Other programs	10,410,336 17,476,880 12,428,988 7,156,120 10,802,853 3,238,612 826,901	- - - - - -	- - - - - -	10,410,336 17,476,880 12,428,988 7,156,120 10,802,853 3,238,612 826,901
Total program expenses Administrative and general expenses	62,340,690 7,027,710	_ _	_ _	62,340,690 7,027,710
Total expenses	69,368,400	_	_	69,368,400
Change in net assets Net assets at beginning of year	35,823,798 587,677,734	10,176,694 25,910,003	258,502 39,250,956	46,258,994 652,838,693
Net assets at end of year	\$623,501,532	36,086,697	39,509,458	699,097,687

See accompanying notes to financial statements.

			2004	
Unrestricted	Temporarily Restricted	Permanently Restricted	TOTAL	
22,458,366 1,246,482 (318,211) 3,968,740	5,335,795 — —	106,696 — —	22,458,366 6,688,973 (318,211) 3,968,740	
27,355,377 80,749,277	5,335,795 6,015,449	106,696 —	32,797,868 86,764,726	
9,649,191 (223,500)	(9,649,191) —		_	
117,530,345	1,702,053	330,196	119,562,594	
9,562,368 12,807,318 11,903,842 6,347,077 10,371,832 2,336,303 1,161,863	- - - - - -		9,562,368 12,807,318 11,903,842 6,347,077 10,371,832 2,336,303 1,161,863	
54,490,603 6,475,422	_	_ _	54,490,603 6,475,422	
60,966,025	_	_	60,966,025	
56,564,320 531,113,414	1,702,053 24,207,950	330,196 38,920,760	58,596,569 594,242,124	
587,677,734	25,910,003	39,250,956	652,838,693	

STATEMENTS OF CASH FLOWS

Years ended June 30, 2005 and 2004

	2005	2004
Cash flows from operating activities:		
Change in net assets	\$46,258,994	58,596,569
Adjustments to reconcile increase in net assets to net		
cash used in operating activities:	7 175 000	7 704 405
Depreciation Net gains on investments	7,175,082 (68,562,395)	7,794,105 (80,363,758)
Contributions of stock	(1,408,922)	(1,261,267)
Losses on disposals of property	15,971	318,211
Amortization of bond issuance costs and discount	39,957	46,574
Contributions and investment income restricted for long-term investment		(1,708,636)
(Increase) decrease in assets:	. (3,034,310)	(1,700,000)
Receivables	(553,149)	(141,267)
Accrued investment income	(97,468)	(376)
Increase (decrease) in liabilities:	(0.,.00)	(3.3)
Accounts payable and accrued expenses	3,262,243	(967,990)
Deferred revenue	219,730	(828,847)
Accrued postretirement benefits	1,955,000	2,311,000
Net seek week in angusting esticities	(45, 200, 007)	(4.0.005,000)
Net cash used in operating activities	(15,389,927)	(16,205,682)
Cash flows from investing activities:		
Acquisition of property and equipment	(5,050,401)	(9,333,952)
Construction of telescope, facilities, and equipment	(16,545,615)	(10,423,095)
Proceeds from sales of property and equipment	_	27,323
Investments purchased	(541,308,692)	(260,313,717)
Proceeds from investments sold or matured	560,978,123	283,192,446
Proceeds from sales of investments by bond trustee	13,288,949	11,327,438
Net cash provided by investing activities	11,362,364	14,476,443
Net dusti provided by investing detivities	11,502,504	14,470,440
Cash flows from financing activities:		
Bond issuance costs capitalized	_	(91,887)
Proceeds from contributions and investment income restricted for:		
Investment in endowment	300,000	360,025
Investment in property and equipment	3,394,970	1,348,611
Net cash provided by financing activities	3,694,970	1,616,749
The case promata symmetric grant and the case of the c	2,00 .,0.0	1,010,1.10
Net decrease in cash and cash equivalents	(332,593)	(112,490)
Cash and cash equivalents at beginning of year	518,726	631,216
Cash and cash equivalents at end of year	\$186,133	518,726
Consideration and flavoring weaking		
Supplementary cash flow information:	¢0.170.100	1 017 100
Cash paid for interest	\$2,170,122	1,917,108
Noncash activity – contributions of stock	1,408,922	1,261,267
See accompanying notes to financial statements.		

NOTES TO FINANCIAL STATEMENTS

(1) Organization and Summary of Significant Accounting Policies

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, Terrestrial Magnetism, Global Ecology, the Geophysical Laboratory, and the Observatories. Income from investments represented approximately 67% and 73% of Carnegie's total revenues for the years ended June 30, 2005 and 2004, respectively. Carnegie's other sources of income are primarily gifts and federal grants and contracts.

Basis of Accounting and Presentation

The financial statements are prepared on the accrual basis of accounting. Contribution revenue is classified according to the existence or absence of donor-imposed restrictions. Satisfaction of donor-imposed restrictions are reported as releases of restrictions in the statements of activities.

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 investment securities 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.

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.

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 (*Investments and Cash Equivalents*) 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 and 2002 revenue bonds payable is estimated to be the carrying value, since these bonds bear adjustable market rates (see note 6).

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.

Use of Estimates

The preparation of financial statements in conformity with accounting principles generally accepted in the United States of America requires management to make estimates and assumptions that affect reported amounts and disclosures in the financial statements. Actual results could differ from those estimates.

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

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 one year or more from the date of 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.

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.

Grants

Carnegie records revenues on grants from federal agencies 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.

Allocation of Costs

The costs of providing programs and administration have been summarized in the statements of activities. Accordingly, certain costs have been allocated among the programs and supporting services benefited. Fundraising expenses of \$615,996 and \$647,977 for the years ended June 30, 2005 and 2004, respectively, have been included in administrative and general expenses in the accompanying statements of activities.

Reclassifications

Certain reclassifications have been made to the 2004 amounts to conform to the 2005 presentation.

(2) Contributions Receivable

Contributions receivable are summarized as follows at June 30, 2005:

Unconditional promises expected to be collected in:

Less than one year	\$3,039,013
One year to five years	4,960,729
	7,999,742
Less:	
Allowance for uncollectible amounts	(6,000)
Discount to present value	(533,938)
	\$7,459,804

Pledges receivable as of June 30, 2005 and 2004 were discounted at rates ranging from 2.54% to 4.13%. The allowance for uncollectible amounts and discount to present value were \$8,500 and \$397,322, respectively, as of June 30, 2004.

(3) Investments

Investments at fair value consisted of the following at June 30, 2005 and 2004:

	2005	2004
Time deposits and money market funds	\$55,825,078	51,168,508
Debt mutual funds	_	26,596
Debt securities	68,048,149	86,251,775
Equity securities	160,682,208	150,678,506
Limited real estate partnerships	35,810,745	39,575,148
Limited partnerships	320,705,415	263,069,177
	\$641,071,595	590,769,709

Investment income, net consisted of the following for the years ended June 30, 2005 and 2004:

	2005	2004
Interest and dividends	\$9,024,867	7,487,625
Net realized gains	48,633,590	41,020,315
Net unrealized gains	19,928,805	39,343,443
Less investment management expenses	(1,026,502)	(1,086,658)
	\$76.560.760	86,764,726

As of June 30, 2005 and 2004, respectively, the fair value for approximately \$434.3 million and \$361.3 million of Carnegie's limited real estate partnership and limited partnership investments has been estimated by the general partners 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, 2005 and 2004:

	2005	2004
Buildings and improvements	\$54,750,109	53,023,675
Scientific equipment	30,314,342	37,953,848
Telescopes	92,277,742	81,634,844
Construction in progress	30,630,550	14,880,288
Administrative equipment	2,594,566	2,370,705
Land	817,117	787,896
Art	38,105	38,105
	211,422,531	190,689,361
Less accumulated depreciation	(52,204,329)	(45,876,121)
	\$159,218,202	144,813,240

Construction in progress consisted of the following at June 30, 2005 and 2004:

	2005	2004
Buildings	\$26,717,890	12,009,263
Scientific equipment	3,912,660	2,871,025
	\$30,630,550	14,880,288

At June 30, 2005 and 2004, approximately \$82.8 million and \$84.2 million, respectively, of construction in progress and other property, net of accumulated depreciation, was located in Las Campanas, Chile. During construction in 2005 and 2004, Carnegie capitalized interest costs of approximately \$562,000 and \$615,000, 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 are expected to cover 50% of the total expected costs. As of June 30, 2005, \$36.0 million has been received. These monies are being used by Carnegie to finance part of the Magellan Telescopes' construction costs. As of June 30, 2005 and 2004, the excess of university members' contributions over operating costs totaled approximately \$31.7 million and \$32.5 million, respectively, and is included in deferred revenue in the accompanying statements of financial position. The deferred revenue is being recognized ratably as income over the remaining estimated useful lives of the telescopes.

(6) Bonds Payable

1993 California Educational Facilities Authority Revenue Bonds

On November 1, 1993, Carnegie issued \$17.5 million each of Series A and 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. The

balances outstanding at June 30, 2005 and 2004, on the Series A issue totaled \$17,500,000 and \$17,500,000, respectively, and on the Series B issue totaled \$17,500,000 and \$17,500,000, respectively. The balances outstanding are net of unamortized bond issue costs and bond discount.

Series A bonds bear interest at 5.6% payable in arrears semiannually on each April 1 and October 1 and upon maturity on October 1, 2023. Series B bonds bear interest at variable money market rates (ranging from 0.97% to 2.53% during the year, and 2.12% at June 30, 2005) 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, 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 Series A and B bonds until the October 1, 2023, maturity date. Sinking fund redemptions begin in 2019 in installments for both series. The fair value of Series A bonds payable at June 30, 2005 and 2004, based on quoted market prices is estimated at \$20.8 million and \$19.1 million respectively. The fair value of Series B bonds payable at June 30, 2005 and 2004 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.

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 August 2005.

The balance outstanding at June 30, 2005 and 2004 on the Carnegie 2002 Series totaled approximately \$29.7 million. The balance outstanding is net of unamortized bond issue costs. Bond proceeds held by the trustee and unexpended at June 30, 2005 and 2004 totaled approximately \$4.9 million and \$18.2 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 .99% and 3.00% during the year ended June 30, 2005 (see note 7). The rate at June 30, 2005 was 2.40%. 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, 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, 2005.

Notes to Financial Statements

(7) Interest Rate Swap Agreement

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:

October 1	
\$3,000,000	2033
3,000,000	2034
3,000,000	2035
3,000,000	2036

The interest rate swap agreement was 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 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 a liability of \$1,456,776 in 2005 and an asset of \$174,107 in 2004. These amounts are included in accounts payable and accrued expenses and accounts receivable, respectively, on the accompanying statements of financial position. The change in fair value for the years ended June 30, 2005 and 2004 was a loss of \$1,630,883 and a gain of \$1,420,726, respectively, and is reported as other income or loss.

(8) Employee Benefit Plans

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 \$3.2 million and \$3.0 million for the years ended June 30, 2005 and 2004, respectively.

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 \$623,000 and \$532,000 for the years ended June 30, 2005 and 2004, respectively.

The expense for postretirement benefits for the years ended June 30, 2005 and 2004 consists of the following:

	2005	2004
Service cost-benefits earned during the year	\$1,151,000	1,233,000
Interest cost on projected benefit obligation	1,184,000	1,214,000
Amortization of gain	243,000	396,000
Postretirement benefit cost	\$2.578.000	2.843.000

The 2005 postretirement benefits expense was approximately \$1,955,000 more than the cash expense of \$623,000, and the 2004 postretirement benefits expense was approximately \$2,311,000 more than the cash expense of \$532,000. 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, 2005 and 2004 follows:

	2005	2004
Change in benefit obligation:		
Benefit obligation at beginning of year	\$19,200,000	20,531,000
Service cost	1,151,000	1,233,000
Interest cost	1,184,000	1,214,000
Actuarial loss	(105,000)	(3,246,000)
Benefits paid	(623,000)	(532,000)
Benefit obligation at end of year	20,807,000	19,200,000
Change in plan assets: Fair value of plan assets at beginning of year Actual return on plan assets	_	_
Contribution to plan	623,000	532,000
Benefits paid	(623,000)	(532,000)
Fair value of plan assets at end of year	_	_
Funded status	(20,807,000)	(19,200,000)
Unrecognized net actuarial loss	5,182,000	5,530,000
Accrued benefit cost	\$(15,625,000)	(13,670,000)

The present value of the benefit obligation as of June 30, 2005 was determined using an assumed discount rate of 5.25%. The present value of the benefit obligation as of June 30, 2004 was determined using an assumed discount rate of 6.25%. Carnegie's policy is to fund postretirement benefits as claims and administrative fees are paid.

For measurement purposes, an 11% annual rate of increase in medical claims was assumed for 2005; the rate of increase was assumed to decrease over the next eight years, eventually reaching 5.5% in 2013 and remain at that level thereafter. The healthcare cost trend rate assumption has a significant effect on the amounts reported. A one-percentage point change in assumed annual healthcare cost trend rate would have the following effects:

One-percentage		One-percentage
	point increase	point decrease
Effect on total of service and interest cost component	s \$786,000	(481,000)
Effect on postretirement benefit obligation	3,996,000	(3,118,000)

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

Carnegie expects to contribute approximately \$539,000 to its postretirement benefit plan during the year ended June 30, 2005.

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

2006	\$539,000
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

Temporarily Restricted Net Assets

Temporarily restricted net assets were available to support the following purposes at June 30, 2005 and 2004:

	2005	2004
Specific research programs	\$13,782,554	21,862,442
Equipment acquisition and construction	20,102,408	1,839,320
Passage of time	2,201,735	2,208,241
	\$36,086,697	25,910,003

Permanently Restricted Net Assets

Permanently restricted net assets consisted of endowed gifts, the income from which is available to support the following purposes at June 30, 2005 and 2004:

	2005	2004
Specific research programs	\$14,799,327	14,322,737
Equipment acquisition and construction	2,710,131	2,704,719
General support (Carnegie endowment)	22,000,000	22,000,000
	\$39,509,458	39,027,456

Net Assets Released from Restrictions and Clarification of Donor Intent

During 2005 and 2004, Carnegie met donor-imposed requirements on certain gifts and, therefore, released temporarily restricted net assets as follows:

	2005	2004
Specific research programs	\$2,126,125	3,686,708
Equipment acquisition and construction	2,139,930	4,114,912
Passage of time	44,000	1,847,571
	\$4,310,055	9,649,191

During 2004, Carnegie allocated \$223,500 of unrestricted net assets to establish a Plant Biology endowment fund to match a donor's contribution. This amount is included as specific research programs 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 amount of the original contract was approximately \$590,000, \$448,552 of which remained outstanding at June 30, 2005.

Carnegie entered into a contract with Johns Hopkins University for the construction of the Singer Building at the Department of Embryology. As of June 30, 2005, approximately \$3.5 million remained outstanding under this contract.

Carnegie entered into a contract on July 1, 2005 for the construction of a new experiment building at the Broad Branch Road facility for approximately \$2.1 million.

Carnegie entered into a contract for the construction of scientific equipment for approximately \$2.3 million. As of June 30, 2005, the outstanding balance was approximately \$1.3 million. Carnegie has outstanding commitments to invest approximately \$96.1 million in limited partnerships at June 30, 2005.

(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, in-kind 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 \$2,419,419 and \$4,655,832, for the years ended June 30, 2005 and 2004, respectively.

SCHEDULES OF EXPENSES

Years ended June 30, 2005 and 2004

			2005
	Carnegie Funds	Federal and Private Grants	Total Expenses
Personnel costs:			
Salaries	\$15,223,153	5,651,882	20,875,035
Fringe benefits and payroll taxes	10,449,769	2,590,285	13,040,054
Total personnel costs	25,672,922	8,242,167	33,915,089
Fellowship grants and awards	2,382,882	861,146	3,244,028
Depreciation	7,175,082	_	7,175,082
General expenses:			
Educational and research supplies	2,360,464	6,644,457	9,004,921
Building maintenance and operation	3,550,364	3,745,749	7,296,113
Travel and meetings	1,087,849	910,420	1,998,269
Publications	33,481	50,210	83,691
Shop	117,856	8,743	126,599
Telephone	195,911	3,212	199,123
Books and subscriptions	258,211	_	258,211
Administrative and general	1,794,191	319,955	2,114,146
Facilities construction	14,211,686	_	14,211,686
Interest	1,859,438	_	1,859,438
Printing and copying	61,195	332	61,527
Shipping and postage	108,677	15,406	124,083
Insurance, taxes, and professional fees	1,937,423	236,356	2,173,779
Equipment	3,793,086	2,008,182	5,801,268
Fundraising expense	615,996	_	615,996
Total general expenses	31,985,828	13,943,022	45,928,850
Total direct costs	67,216,714	23,046,335	90,263,049
Indirect costs:			
Grants and contracts	(7,400,796)	7,400,796	_
Total costs	59,815,918	30,447,131	90,263,049
Capitalized scientific equipment and facilities	(19,061,636)	(1,833,013)	(20,894,649)
Total expenses	\$40,754,282	28,614,118	69,368,400

See accompanying independent auditors' report.

		2004	
Carnegie Funds	Federal and Private Grants	Total Expenses	
14,475,943 10,009,374	4,780,166 2,238,258	19,256,109 12,247,632	
24,485,317	7,018,424	31,503,741	
1,966,003	948,967	2,914,970	
7,794,105	_	7,794,105	
2,438,265 8,409,920 1,021,637 40,854 99,989 201,400 342,961 1,299,174 8,530,528 1,771,130 77,751 169,309 2,759,936 1,724,656 647,977	5,232,412 117,067 746,156 31,977 23,649 5,631 — 186,264 — 24,681 72,450 1,673,942	7,670,677 8,526,987 1,767,793 72,831 123,638 207,031 342,961 1,485,438 8,530,528 1,771,130 77,751 193,990 2,832,386 3,398,598 647,977	
29,535,487	8,114,229	37,649,716	
63,780,912	16,081,620	79,862,532	
(6,376,746)	6,376,746	_	
57,404,166	22,458,366	79,862,532	
(17,424,577)	(1,471,930)	(18,896,507)	
39,979,589	20,986,436	60,966,025	

Carnegie Institution

PERSONNEL July 1, 2004-June 30, 2005

Carnegie Administration

Lloyd Allen, Building Maintenance Specialist 1 Sharon Bassin, Assistant to the President/Assistant Secretary to the Board Andrea Bremer, Business Coordinator² 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 Linda Feinberg, Manager of External Affairs Charles Fonville, Lobby Attendant3 Susanne Garvey, Director of External Affairs Claire Hardy, Database and Communications Coordinator Charles Hargrove, Project Archivist⁴ Darla Keefer, Administrative Secretary Ann Keyes, Payroll Coordinator Charles Kim, Systems Administrator 5 Jeffrey Lightfield, Deputy to the Financial Manager John Lively, Director of Administration and Finance Rhoda Mathias, Secretary to the President Tina McDowell, Editor and Publications Officer Richard Meserve, President Ann Mulfort, Project Archivist6 Trong Nguyen, Financial Accountant Michael Pimenov, Endowment Manager Arnold Pryor, Facilities Coordinator Gotthard Sághi-Szabó, Chief Information Officer⁷ Jennifer Snyder, Project Archivist John Strom, Web Manager Kris Sundback, Financial Manager Vickie Tucker, Administrative Coordinator/Accounts Payable Yulonda White, Human Resources and Insurance Records Coordinator Jacqueline Williams, Assistant to Manager, Human Resources and Insurance

¹To May 6, 2005 ²To November 15, 2004 ³To June 30, 2005 ⁴To December 3, 2004 ⁶To August 4, 2004 ⁶From January 3, 2005 ⁷From September 1, 2004

Carnegie Academy for Science Education

Dayo Akinsheye, Mentor Teacher¹ Jessica Baldwin, Mentor Teacher¹ Sarah Bax, Mentor Teacher^{1,2} Inés Cifuentes, Director³ Asonja Dorsey, Mentor Teacher^{1,2} VanNessa Duckett, Mentor Teacher² Audrey Edmonds, Intern² Julie Edmonds, Associate Director⁴, Codirector³ Ricky Gabray, Intern² Dominic Gasaway, First Light Assistant³ Joseph Geglia, Intern² Kendra Hardman, Intern¹, First Light Assistant³ Anne Hemphill, Mentor Teacher² Toby Horn, Secondary Programs⁴, Codirector³ Adedoyin Kalejaiye, Intern² Loretta Kelly, Mentor Teacher² Lynn Lahti-Hommeyer, Mentor Teacher² Rebecca Lippy, Intern² Akriti Mathur, Intern1 Asha Mathur, Mentor Teacher 1 Fran McCrackin, Mentor Teacher 1,2 Kelliston McDowell, Intern1 Thomas Nassif, Mentor Teacher² Maxine Singer, Senior Scientific Advisor4 Claire Sontag, Mentor Teacher 1 John Tatum, Mentor Teacher² Gregory Taylor, CASE Technology Instructor1 Annie Thompson, Mentor Teacher 1,2 Latisha Whitley, Intern 1,2 Beverly Williams, Mentor Teacher² Haimanot Worku, Intern²

¹Summer Institute 2004 ²Summer Institute 2005 ³Through June 2005 ⁴Through December 2004

Embryology

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Douglas E. Koshland
Allan C. Spradling, *Director*Yixian Zheng

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Eugenia Dikovskaia, Animal Facility Manager¹⁴
Christopher Edwards, Technician
Pat Englar, Director's Administrative Assistant
Lea Fortuno, Animal Care Technician
Nicole Gabriel, Animal Care Technician
Oliver Gibbon, P/T Lab Assistant¹⁶
Aja Green, Technician



First row (right to left): Yung-Shu Kuan, Ellen Cammon, Marnie Halpern, Pat Cammon, Ben Ohlstein, Ella Jackson, Yan Tan, Aja Green, Lea Fortuno. Second row (right to left): Allisandra Wen, Kiran Santhakumar, Eileen Hogan, Dave MacPherson, Dean Calahan, Dan Ducat. Third row (stairs, top to bottom): Tina Tootle, Jovita Diaz, Catherine Huang, Anna Krueger, Margaret Hoang, Karina Conkrite, Stephanie Owen, Elcin Unal, Rejeanne Juste, Eugenia Dikovskaia, Queenie Vong. Fourth row (stairs, top to bottom): Joe Gall, Shusheng Wang, Dan Lighthouse, Ona Martin. Fifth row (stairs, top to bottom): Cynthia Wagner, Christine Pratt, Bishu Das, Judy Yanowitz, Tara Hardiman, Sara Clatterbuck, Rafael Villagaray, Kai Sung, Liang Liang, Zheng'an Wu, Ji-Long Liu, Ebony Faux. Sixth row (stairs, top to bottom): Andrew Skora, Mike Buszczak, Christoph Lepper, Bob Levis, Alex Schreiber, Jim Wilhelm, Allan Spradling, Mike Sepanski, Yixian Zheng, Mahmud Siddiqi, Doug Koshland, Cheng Xu. Seventh row (stairs, top to bottom): Dan Gorelick, Todd Nystul, Hong-Guo Yu, Tom McDonaugh, Warren Hall, Don Brown, Alex Bortvin.

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¹From September 1, 2004 ²To December 15, 2004 ³From May 2, 2005 ⁴To December 31, 2004 ⁵To June 15, 2005 ⁶To December 22, 2004 ⁷From July 1, 2004 ⁸To August 31, 2004

⁹From May 16, 2005 ¹⁰To June 30, 2005 ¹¹From July 15, 2004 ¹²To June 22, 2005 ¹³To November 30, 2004 ¹⁴From October 4, 2004 ¹⁵From May 17, 2005 ¹⁶From February 1, 2005 ¹⁷From May 31, 2005 ¹⁸From August 2, 2004 ¹⁹To July 30, 2004 ²⁰To May 13, 2005 ²¹From March 7, 2005 ²²To May 31, 2005 ²³From September 29, 2005 ²⁴From January 1, 2005

Geophysical Laboratory

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Members of the Geophysical Laboratory staff are shown in November 2005. First row (from left): Z. Wu, V. Starke, H. Watson, B. Mysen, D. Rumble, R. Hazen, A. Goncharov, W. Huntress, Y. Fei, P. Esparza, D. George, M. Phillips. Second row: J. Chen, M. Aihaiti, unidentified, M. Somayazulu, X. Sha, Y. Wang, S. Keshav, J. Jackson, O. Degtyareva, V. Degtyareva, D. Sverjensky, S. Schmidt, M. Fogel, P. Morrill, S. Ono, B. Brown, P. Roa, S. Ho, S. Krasnicki, P. Meeder. Third row: A. Bekker, M. Schrenk, B. Militzer, J. Eigenbrode, E. Cottrell, R. Martin, H. Yabuta, C. Hadidiacos, P. Zelanko, G. Maule, M. Roskosz, M. Wolf, S. Coley, S. Jacobsen, J. Xu, S. Hodge, S. Hardy, G. Huntress, M. Imlay, M. Fries, G. Sághi-Szabó. Missing from picture: N. Boctor, R. Caracas, X. Chen, Y. Chen, J. Ciezak, G. Cody, R. Cohen, A. Corgne, P. Dera, S. Gramsch, P. Griffin, R. Hemley, N. Irvine, T. Jenkins, J. Lai, A. Mao, H. Mao, J. Scott, H. Shu, J. Shu, S. Southard, A. Steele, J. Straub, V. Struzhkin, Y. Thomas, J. Vorberger, C. Yan.

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4

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Zeming Zhang, Academia Sinica, China

Guangtian Zou, Center for Superhard Materials, Jilin University, Changchun, China

¹To June 30, 2005

²From July 6, 2004

³To July 31, 2004

⁴To August 31, 2004

⁵To February 1, 2005

⁶To October 27, 2004 ⁷From August 1, 2004

⁸From July 1, 2004

⁹To September 22, 2004

¹⁰From January 1, 2005

¹¹From September 16, 2004

12To July 9, 2004

¹³To December 9, 2004

¹⁴From January 5, 2005

¹⁵From December 7, 2004

¹⁶From January 11, 2005

¹⁷From September 1, 2004, to June 30, 2005

¹⁸To November 1, 2004

¹⁹From January 13, 2005

²⁰From August 4, 2004

²¹From January 19, 2005

²²To February 28, 2005

²³From July 6, 2004, to June 17, 2005

²⁴Joint appointment with DTM

²⁵To December 3, 2004

²⁶From January 1, 2005

²⁷From July 19, 2004

²⁸To September 2, 2004

²⁹From June 1, 2005

Global Ecology

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¹To January 15, 2005
²To February 1, 2005
³From January 5, 2005
⁴To July 15, 2004
⁵To August 31, 2004
⁶From August 1, 2004
⁷To December 15, 2004
⁸To June 15, 2005
⁹To June 22, 2005
¹⁰To December 9, 2004
¹¹From September 16, 2004
¹²To September 30, 2005
¹³From July 27, 2004
¹⁴To July 31, 2004
¹⁵To July 31, 2004



Members of the Global Ecology staff are shown in December 2005. First row from left: Ismael Villa, Maoyi Huang, Jan Brown, Angelica Velasquez, Kathi Bump, George Merchant, Chris Field, Paul Sterbentz. Middle row: Paulo Oliveira, Kim Carlson, Adam Wolf, Yuka Estrada, Bob Haxo, Linda Longoria, Renee Wang, Susan Cortinas, Yingping Wang. Back row: Halton Peters, Deborah Tausch, Joe Berry, Glenn Ford, Mary Smith, David Lobell, Alison Appling, Jason Funk, Todd Tobeck, Natalie Boelman, Ben Houghton.

¹⁶From October 1, 2004, to March 30, 2005

¹⁷From July 1, 2004, to October 9, 2004

¹⁸To August 4, 2004

¹⁹To August 10, 2004

²⁰To June 8, 2005

The Observatories

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SUPPORT SCIENTIST

David Murphy, Instrument Scientist

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Arnold Phifer, Director of External Affairs8

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Jerson Castillo, Instrument Maker

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Silvia Hutchison, Assistant to the Director

Sharon Kelly, Buyer

Kathleen Koviak, Data Analyst

Vincent Kowal, Machine Shop Foreperson/Instrument Maker

Elsa Luna, Comptroller Becky Lynn, Secretary Greg Ortiz, Assistant B

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Juan Alfaro, GMT Site Maintenance Support 12

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Johnny Chavez, Chef Assistant 15

Carlos Contreras, Science Support 16

Angel Cortés, Accountant Henry Cortés, Electrician 17

José Cortés, Janitor

Jorge Cuadra, Mechanic Assistant

Oscar Duhalde, Magellan Small Telescope Technician

Julio Egaña, Painter

Juan Espoz, Mechanic

Javier Fuentes, GMT Site Testing Support 18

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Sergio González, Science Support

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Luis Gutiérrez, Mechanic

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Marc Leroy, Assistant Manager 19

Leonel Lillo, Carpenter

Gabriel Martin, Magellan Instrument Specialist

Marcos Medina, Chef

Miguel Méndez, Magellan Welder

Victor Meriño, Magellan Telescope Operator

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Javier Rivera, Paramedic

Honorio Rojas, Water Pump Operator

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¹From August 1, 2004 ²From March 1, 2005 ³From August 25, 2004 ⁴To June 30, 2005 ⁵From September 1, 2004 ⁶From November 1, 2004 ⁷To June 30, 2005 ⁸From August 23, 2004 ⁹From October 18, 2004 10From March 7, 2005 ¹¹From August 31, 2004, to October 15, 2004 ¹²From July 1, 2004 ¹³To May 23, 2005 ¹⁴From June 1, 2005 ¹⁵From March 18, 2005 ¹⁶From May 30, 2005 ¹⁷From June 1, 2004 ¹⁸From April 5, 2005 ¹⁹From January 1, 2005; formerly Electronics Engineer ²⁰From August 3, 2004

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Plant Biology

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IMAGE COURTESY PAUL STERBENTZ.

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¹To March 31, 2005 ²From January 7, 2005 ³To September 10, 2005

⁴ From November 1, 2004, to June 30, 2005
5Enam March 2005 to June 30, 2005
⁵ From May 1, 2005, to June 8, 2005
⁶ From September 20, 2004, to May 5, 2005
⁷ From April 25, 2005
⁸ From July 5, 2004, to December 31, 2004
⁹ From June 30, 2004
¹⁰ To February 2, 2005
¹¹ To December 14, 2004
¹² To December 31, 2004
¹³ To December 20, 2004
¹⁴ From November 8, 2004
¹⁵ To January 6, 2005
¹⁶ From January 2, 2005
¹⁷ To April 14, 2005
¹⁸ From July 1, 2004
19Erom January 1, 2005, to April 20, 2005
¹⁹ From January 1, 2005, to April 20, 2005
²⁰ From May 1, 2004
²¹ To June 30, 2005
²² From April 1, 2005
²³ To January 31, 2005
²⁴ From November 1, 2004
²⁵ From January 1, 2005
²⁶ From September 1, 2004
²⁷ To October 8, 2004
²⁸ From May 2, 2005
²⁹ From April 5, 2005
³⁰ To June 16, 2005
³¹ To August 28, 2004
³² From October 1, 2004
³³ From September 17, 2004, to June 30, 2005
³⁴ From July 1, 2004
³⁵ From July 26, 2004
³⁶ From March 4, 2005, to June 30, 2005
³⁷ From October 4, 2004
³⁸ To April 8, 2005
³⁹ From April 9, 2005
40From August 18, 2004
⁴¹ From February 16, 2005
42Eman July 2, 2004
⁴² From July 2, 2004
⁴³ From March 1, 2005
⁴⁴ From June 16, 2005
⁴⁵ From November 23, 2004, to May 27, 2005
⁴⁶ To April 8, 2005
⁴⁷ From November 4, 2004
⁴⁸ From February 1, 2005
⁴⁹ To August 15, 2005
⁵⁰ From June 25, 2005
⁵¹ From June 13, 2005, to June 30, 2005
⁵² From July 1, 2004, to August 31, 2004
⁵³ To July 20, 2004
⁵⁴ From June 28, 2004
⁵⁵ From July 1, 2004, to June 15, 2005
⁵⁶ From February 25, 2005
⁵⁷ From January 24, 2005
⁵⁸ From April 25, 2005
⁵⁹ To July 31, 2004

61To September 15, 2004

⁶²To September 30, 2004

Terrestrial Magnetism

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³To January 2, 2005 ⁴From July 7, 2004 ⁵To April 1, 2005 ⁶From February 15, 2005 ⁷From April 4, 2005 ⁸From September 1, 2004 ⁹From July 27, 2004 ¹⁰To August 4, 2004 ¹¹To August 31, 2004 ¹²From July 1, 2004 ¹³From September 1, 2004 ¹⁴From October 15, 2004 ¹⁵From December 12, 2004 ¹⁶Joint appointment with Geophysical Laboratory ¹⁷To June 30, 2005 ¹⁸From June 6, 2005

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