CarnegieScience

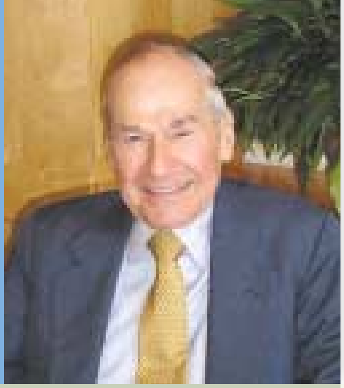
THE NEWSLETTER OF THE CARNEGIE INSTITUTION [SUMMER 2006]

[PAGE 12]

Inside

Carnegie Trustees Meet in May 3
Carnegie Welcomes Michael Brin to the Board 3
Lab-on-a-Chip Ready to Go 3
"Hooked on Carnegie": Meet Senior Trustee Jim Weinberg 4
The Geophysical Laboratory Celebrates 100 Years of Science! 5
Astrobiology Comes to Washington 6
Gene Mutation Causes Lethally Low-Fat Diet 8
Growing Solutions to the Energy (and Climate) Crisis 9
Hunting for Black Holes 12
Oceans May Soon Be More Corrosive Than When the Dinosaurs Died 14
In Brief 15
The Giant Magellan Telescope Group Grows 20
Capital Science Evenings 20

- DEPARTMENT OF EMBRYOLOGY
- GEOPHYSICAL LABORATORY
- DEPARTMENT OF GLOBAL ECOLOGY
- THE OBSERVATORIES
- DEPARTMENT OF PLANT BIOLOGY
- DEPARTMENT OF TERRESTRIAL MAGNETISM
- CASE/ FIRST LIGHT



I am constantly amazed by the number of extraordinary achievements that arise from the work of the institution's 70 staff scientists. On the face of it our mission—to support the highly creative research of "exceptional individuals" for the improvement of mankind—might suggest that Carnegie researchers work in isolation. Nothing could be further from the truth. In addition to individual projects and participation in group endeavors, countless collaborative efforts, driven by the vision of individual researchers, fill our 100-year history. These partnerships have made us stronger, galvanized our reputation for inspired work, and introduced many others to the Carnegie culture.

Carnegie's collaborations date back to the early days of the institution. In 1914, as one example, archaeologist Sylvanus Morley was intent on understanding the ancient Mayan civilization. Supported by Carnegie, he coordinated with foreign governments and hired legions of local laborers to excavate Chichén Itzá, one of the most important Mayan sites ever discovered. In the 1920s, Harry Oscar Wood was driven to understand and predict earthquakes. He led a Carnegie/Caltech collaboration, which, among other breakthroughs, brought us Charles Richter's famous earthquake-measurement scale.

Today's sophisticated science requires elaborate and expensive instrumentation, and collaborations have become essential. One might think that the unique Carnegie character, with its emphasis on the gifted individual, could be jeopardized in such an environment. But that has not happened. Instead, researchers in other organizations look to Carnegie scientists for their vision and leadership. The Carnegie-led High Pressure Collaborative Access Team, at Argonne National Laboratory's Advanced Photon Source in Illinois, is illustrative. Its high-energy X-rays allow Geophysical Laboratory researchers to probe the properties of matter under extreme conditions. That partnership includes government, universities, and a national lab. However, it is Carnegie scientists, guided by their vision, who lead the effort and manage the facility. The results have made them world leaders in their discipline, and as a consequence, numerous others have been introduced to the "Carnegie way" of research.

The twin 6.5-meter Baade and Clay telescopes would not have been possible without our partners in the Magellan Consortium. Under the Observatories' leadership, these giant eyes on the universe have taken astronomy to a new level by increasing our understanding of the evolution of stars, the riddle of gamma-ray bursts, and many other phenomena. Without group cooperation these instruments would not have been built. Carnegie again had the idea, the drive, and the follow-through, and the payoff has been tremendous.

There are other lesser-known, but equally important, partnerships. The Department of Global Ecology, for instance, recently signed a one-year contract with ImageONE, a Japanese satellite company based in Tokyo. An ImageONE engineer will work with Carnegie researchers to learn ecosystem monitoring techniques. Expanding the reach of this vital research is a perfect example of Andrew Carnegie's original intent to benefit humankind.

Perhaps the most pervasive exposure to the Carnegie way of research has come through our associations with postdoctoral associates and visiting investigators. Each year, Carnegie hosts scores of these scientists. Additionally, staff scientists at the Department of Embryology on The Johns Hopkins University campus, and at the departments of Plant Biology and Global Ecology at Stanford University, hold faculty positions at those schools. The day-to-day interactions with like-minded colleagues at the universities have introduced generations of investigators to our scientific approach.

Andrew Carnegie's founding principles, and our small size, have kept us nimble and influential through the most extraordinary period of change in human history.* Even as the scientific enterprise has exploded, we have been able to maintain and enrich the Carnegie culture. While researchers in every department lead major scientific ventures, they also sustain our core values. Freedom and flexibility are key to our scientists' creativity and will ensure that this small organization continues its expansive reach.

—Michael E. Gellert, *Chairman*

*See R. Meserve, "The President's Commentary," Year Book 2004-2005 (Washington, D.C., Carnegie Institution of Washington, 2006).

Carnegie Institution of Washington

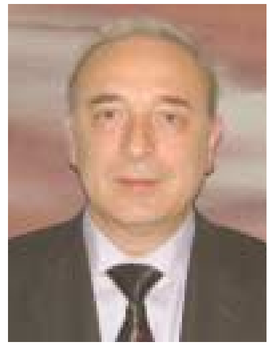
1530 P Street, NW
Washington, D.C.
20005-1910

202.387.6400
www.CarnegieInstitution.org

Carnegie Trustees Meet in May

The 124th meeting of the Carnegie board of trustees took place at the Washington, D.C., administration building on May 4 and 5 following the Geophysical Laboratory's centennial celebration May 3. Among the first orders of business was the election of Dr. Michael Brin to the board. Besides the full board, the Employee Affairs, Finance, Development, and Nominating committees also met. The meetings were accompanied by talks given by all the directors highlighting the work in progress at their departments and a Carnegie Evening lecture on biofuels by Plant Biology director Chris Somerville.

Carnegie Welcomes **Michael Brin** to the Board



Carnegie's newest trustee Michael Brin

University of Maryland mathematics professor Michael Brin was elected to the Carnegie board of trustees May 4. After emigrating from the Soviet Union in 1979, Brin joined the university as an assistant professor in 1980 and became a full professor in 1986. He received his M.A. from Moscow State University in 1970 and his Ph.D. from Kharkov State University, Ukraine, in 1975. He was a researcher/analyst at the Economics Institute in the Soviet Union from 1970 to 1978.

In addition to his research, writing, and lecturing, Brin has taught courses in differential equations and probability, statistics, topology, Riemannian geometry, linear algebra, dynamical systems, and other subjects at varying levels. He is also very active in the mathematics community. Brin's academic and technical expertise will be a valuable asset in guiding Carnegie in the years to come.

Lab-on-a-Chip Ready to Go

In April the Geophysical Laboratory's (GL) Lab-on-a-Chip microbe-detection device went through its final paces in zero gravity on NASA's new parabolic flight aircraft, the C-9, before launch to the International Space Station (ISS) scheduled for early 2007. GL's Jake Maule and collaborator Norm Wainwright from Charles River Laboratories performed tests to examine if liquid samples could be handled effectively in zero-g without any material escaping into the cabin environment. The tests went well. Maule subsequently trained the astronaut crew to work the device.

(Images courtesy Reduced Gravity Office, NASA Johnson Space Center.)

NASA's new C-9 parabolic aircraft during ascent (above left) and descent (above right); Jake Maule and Norm Wainwright (right) test GL's Lab-on-a-Chip in zero-g.

"HOOKED ON CARNEGIE": Meet Senior Trustee Jim Weinberg

Senior trustee Sidney J. (Jim) Weinberg, Jr.

"It was Carnegie trustee Bill Greenough, CEO of TIAA-CREF, who introduced me to the institution," recalled Sidney J. (Jim) Weinberg, Jr., Carnegie senior trustee. "Bill and I knew each other through the Carnegie Foundation for the Advancement of Teaching. He suggested that I meet Carnegie president Jim Ebert. I did. The institution and its history was so interesting, I was hooked."

Weinberg was elected to the Carnegie board in 1983. He initially served as a member of the finance committee. In 1984 he became its chairman, a position he held through the late 1980s. He was also a member of the employee benefits committee and became chairman of the nominating committee in 1993, where he introduced Carnegie science to an expanded network of impressive individuals. Over the years he also served on the executive, finance, and capital campaign committees, the Magellan campaign committee, and the Observatories visiting committee. He became a senior trustee in 1999.

With a bachelor's degree from Princeton in public and international affairs and an MBA from Harvard University, Weinberg joined Owens-Corning Fiberglas Corporation in 1949 and subsequently became vice president of the textile fibers division. In the mid-1960s he joined the investment banking firm Goldman Sachs, where he remained as general partner until his retirement in 1988. He is now a senior director.

"Jim often prefaces his remarks at board meetings by saying 'I don't really understand the science, but it seems to me . . .' and then goes on to put his finger right on the critical point," remarked President Emerita Maxine Singer. "It happened often enough that I could even tease him a little bit about it."

Weinberg's counsel has helped guide the institution through an extraordinary period of change. In late 1984 he advised the committee that examined the co-location of the Geophysical Laboratory and the Department of Terrestrial Magnetism. Through his work on the Magellan campaign committee and the Observatories visiting committee, he helped the institution successfully navigate the challenging maze of issues associated with the Magellan twin 6.5-meter telescope project at the Las Campanas Observatory in Chile. Both telescopes and instrumentation are operational and are unsurpassed in their quality.

Weinberg's support for and dedication to education and scientific research go well beyond Carnegie. Among his many affiliations, he is a trustee emeritus of Scripps College, an honorary trustee of the Woods Hole Oceanographic Institution, and a life trustee of the New York Presbyterian Hospital. He is cofounder and board chair emeritus of the Keck Graduate Institute of Applied Life Sciences, where a new professorship was recently established, the Sidney J. Weinberg, Jr. Professor of Applied Life Sciences. Weinberg is also a major supporter of the *New York Times* College Scholarship program. In 2005 he was elected a fellow of the American Academy of Arts and Sciences.

Stepping back, Weinberg reflected on his fascination with Carnegie: "Mr. Carnegie's vision, over 100 years ago, of supporting the exceptional vitality of an individual scientific investigator and encouraging him or her to pursue their own visions is legendary. Who could have imagined the new knowledge and understanding of our world and of our universe that this institution has brought about? The trustees and all those associated with Carnegie must ask: Can it be that there are no limits at all to discoveries by extraordinarily gifted scientists?"

"Jim is a very wise man," commented Carnegie president Richard Meserve. "When he speaks at a board or committee meeting, everyone listens carefully. The institution has benefited greatly from his guidance and support."

The Geophysical Laboratory Celebrates **100 Years of Science!**

Former director of the Geophysical Laboratory Charlie Prewitt (left) talks with Mac Ross before dinner at the Broad Branch Road Campus during the centennial celebration.

One hundred years of extraordinary science came to life in just one day at the Geophysical Laboratory's (GL) centennial celebration symposium, held on May 3 at Carnegie's administration building. Eight speakers, all of whom worked at or continue to work at the lab, talked about how GL research has influenced, and often defined, the disciplines of petrology, crystallography, Earth and planetary science, high-pressure/high-temperature studies, and more.

After introductory remarks by Carnegie president Richard Meserve and GL director Wesley Huntress, Doug Rumble introduced the speakers. Davis Young, professor emeritus at Calvin College, talked about the unique character of the lab during its formative years. He touched on the pioneering research of Arthur Day, the lab's first director, and described Norman Bowen's work, which paved the way for the lab's unsurpassed high-pressure research today.

Sue Schmidt (left), who organized the GL centennial festivities, talks with Arnold Pryor of the Carnegie administration.

Former Carnegie postdoctoral fellow Edward Young, currently a professor at UCLA, took the audience on an isotopic "tour" showing how these atomic siblings can be used to chronicle the formation of the infant solar system and understand events such as the rise of Earth's atmosphere. Staff member Dave Mao then described the unique academic environment at the lab and explained how it has fostered innovative research and instrumentation over time. He summarized some of the spectacular payoffs, including advances in understanding what is happening in Earth's deep interior and fundamental aspects of how minerals behave and change under extreme pressures and temperatures.

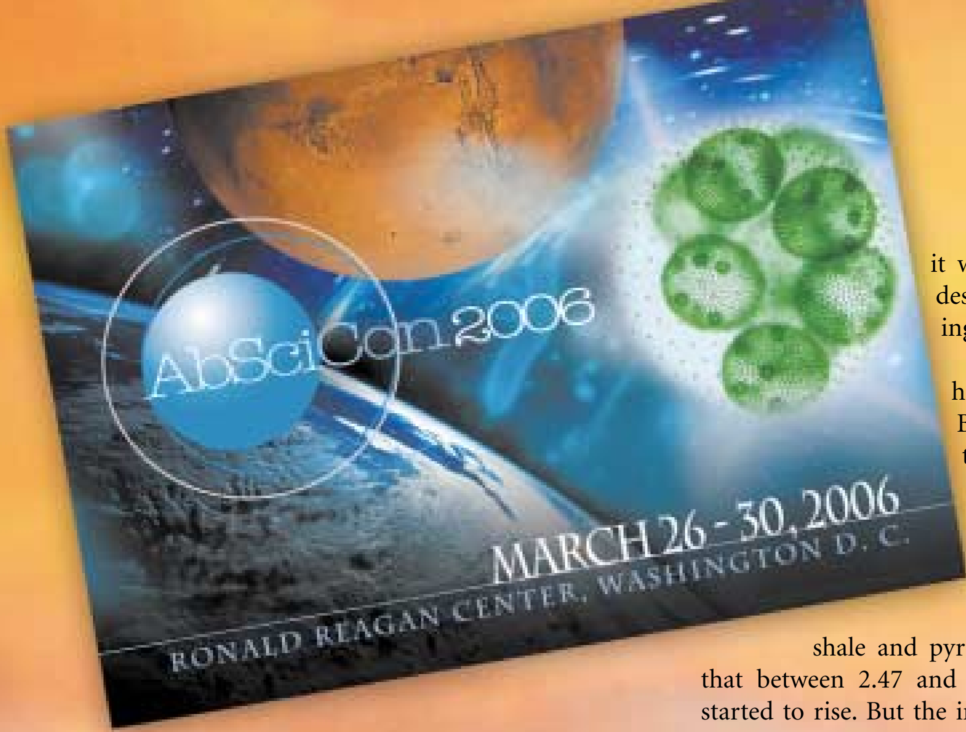
Dean Presnall of the University of Texas at Dallas took the audience back to the early years at the lab and predicted what he thought would become the most important areas of igneous petrology over the coming decades. He was followed by Pascal Richet of the Institut de Physique du Globe in Paris, who addressed advances in the physics of silicate melts. Friedrich Seifert, of Bayerisches Geoinstitut, Universität Bayreuth, then talked about the "slowness" of matter traveling in very dense material deep within the Earth.

Carnegie's chief information officer, Gotthard Sághi-Szabó (left), arrives at the GL centennial celebration with Carnegie trustee Jaylee Mead. Toby Horn, codirector of the Carnegie Academy for Science Education, is in the foreground.

GL's Bob Hazen's fast-paced, picture-intensive presentation explored the evolution and importance of instrumentation at the lab, which has been a driving force behind a century of remarkable discoveries. He too looked down the road and predicted that extreme crystallography, advances in laser heating, and new detectors were in the lab's future.

The last talk of the day, by GL's Marilyn Fogel, emphasized a current research direction of the lab—understanding how life came to be. Carbon, an essential building block of life, was the focus of her talk. Fogel described a variety of research efforts that trace how carbon makes its way through systems—from deep within the Earth, on its surface, and into the atmosphere—both geochemically and biologically, with the ultimate goal of understanding how life emerged from a geochemical world.

After the talks, participants and guests gathered at the Broad Branch Road Campus for tours, cocktails, and dinner.



Astrobiology Comes to Washington

Astrobiology—the interdisciplinary approach to understanding how life arose on Earth and determining whether it exists elsewhere—was on stage in Washington, D.C., the week of March 26, when the Astrobiology Science Conference 2006 convened at the Ronald Reagan Building. Marilyn Fogel of Carnegie's Geophysical Laboratory (GL) chaired the scientific organizing committee, which was heavily populated with other Carnegie researchers from GL and the Department of Terrestrial Magnetism (DTM). A sampling of the Carnegie research presented follows.

See http://abscicon 2006.arc.nasa.gov/ for more details.

Climate Change and the Rise of Atmospheric Oxygen

Today's climate change pales in comparison with what happened as Earth gave birth to its oxygen-containing atmosphere billions of years ago. By analyzing clues contained in rocks, GL scientists found that the initial rise of oxygen (O_2) was transitory and that its final emergence may have been linked to volcanoes and catastrophic glaciations. "Rocks contain fingerprint-like clues to the past environment through specific variations in elements such as sulfur," explained GL's Shuhei Ono. Measuring sulfur isotopes—different versions of the atom with the same number of protons but a different number of neutrons—in rock can monitor ancient oxygen levels. Ono looked at sulfur isotopes from South African drill-core samples from 3.2 to 2.4 billion years ago. Although Earth did not start out with oxygen in the atmosphere, microbes in the oceans could have used methane for energy instead. Around 2.9 billion years ago, the methane-dominated atmosphere provided a greenhouse effect and kept the planet warm. Ono's analysis suggests that when oxygen first appeared in the atmosphere, it would have reacted with the methane, destabilizing the atmosphere and triggering the Mozaan-Witwatersrand glaciation.

The oxygen atmosphere was not here to stay, however. Carnegie's Andrey Bekker noted that "volcanoes peppered the Earth's surface, belching gases and particulates into the atmosphere. That material rained back on the surface and oceans, affecting ocean chemistry and the ocean and atmospheric cycles." Bekker looked at sulfur isotopes in shale and pyrite from Western Australia and found that between 2.47 and 2.463 billion years ago oxygen levels started to rise. But the intense volcanic activity made it almost disappear again. Despite these fits and starts, in the end the oxygen atmosphere prevailed.

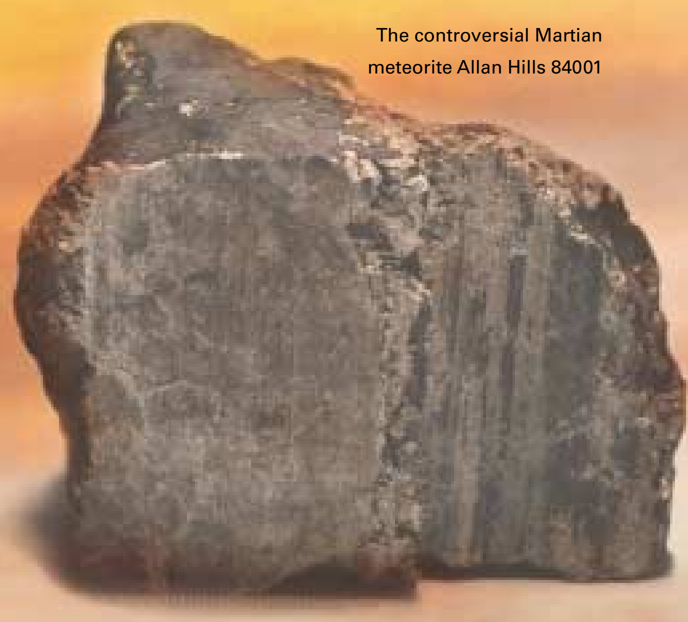
A New Look at Allan Hills

Since the mid-1990s, a great debate has raged over whether organic compounds and tiny globules of carbonate minerals embedded in the Martian meteorite Allan Hills 84001 were processed by living creatures from the Red Planet. Using sophisticated instrumentation, scientists at the Geophysical Laboratory and colleagues* took a fresh look at how material associated with carbonate globules was created. They compared the results with analogous globules from a volcanic complex on Svalbard, an island north of Norway, and concluded that living organisms were not at work.

Ideas on Gas Giant Planet Formation Take Shape

Rocky planets like Earth and Mars are born when small particles smash together to form larger, planet-sized clusters in a planet-

The controversial Martian meteorite Allan Hills 84001



forming disk, but researchers are less sure about how gas giant planets like Jupiter and Saturn form. Is it by core accretion—the process that creates their smaller, terrestrial cousins? Or is it by disk instability—in which the planet-forming disk itself actually fragments into a number of planet-sized clumps? Work from the Department of Terrestrial Magnetism explores both possibilities.

Carnegie Fellow Hannah Jang-Condell devised a method to catch the early stages of gas giant core accretion in the act. If actively accreting cores exist, they should leave a gravitational "dimple" in the planet-forming disk. Since disk instability would result in planet-sized fragments right away, the existence of these young, intermediate-sized cores would be a clear indicator of core accretion.

The gravitational dimples resemble craters on the Moon. Sunlight shines in from the side, leaving the inside of the edge nearest the star in shadow and illuminating the edge facing the star. The bright side heats up and the shadowed side remains cool, yielding a distinct thermal pattern that an Earth-based observer should be able to see in the infrared spectrum. "If we could detect this signature in a protoplanetary disk, it would indicate the presence of a young planetary body that could go on to form a gas giant via core accretion," Jang-Condell said.

In some situations, however, core accretion seems an unlikely model for gas giant planet formation. For example, theoretical computer models by DTM staff member Alan Boss suggest that disk instability best explains planet formation around M dwarf stars—the stars that dominate the stellar population in the solar neighborhood. M dwarf stars have masses from one-tenth to one-half that of the Sun. Core accretion would likely take more than 10 million years around these small, gravitationally weak stars, but disk instability happens quickly enough to yield gas giant planets in as little as 1,000 years.

Cold Case: Looking for Life on Mars

Evidence never dies in the popular TV show *Cold Case*. Nor do some traces of life disappear on Earth, Mars, or elsewhere. An international team of scientists* including researchers from the Geophysical Laboratory has developed techniques to detect minuscule amounts of biological remains, called biosignatures, in the frozen terrain of Svalbard. This technology will be used on future life-search missions to the Red Planet. "One of our studies showed that we can detect even the most minute amounts of the element nitrogen, which can be evidence of life," noted Marilyn Fogel. "Interestingly, rocks might be particularly promising places to find traces left by the tiniest microbes. Svalbard is brittle cold, very dry, and rocky, much like the Martian environment, making it an excellent test bed."

Members of the international Arctic Mars Analogue Svalbard Expedition (AMASE) team conduct research in the harsh, Mars-like environment of Svalbard, an island north of Norway.

(Photo courtesy Kjell Ove Storvik.)

Nitrogen is essential to DNA, RNA, and protein. All life depends on it. The scientists looked at how a certain isotope of nitrogen was distributed in soils, water, rocks, plants, and microbes. They found that nitrogen quantities varied depending on how the element interacted with the environment and living organisms. They also found that organisms leave telltale nitrogen fingerprints on rocks, making the technology well suited for finding remains of life on the rocky terrain of Mars.

In another study, the group found that they could adapt techniques used in genetic laboratories to the field. They found that DNA sampling and the polymerase chain reaction (PCR) method—which makes many copies of a specific segment of DNA for analysis—can detect genetic differences in rock-dwelling communities of blue-green algae (cyanobacteria) and fungi. Further, they identified over 90 different compounds that can be correlated to biosignatures of those life forms. These fingerprints will be part of an enormous library of signatures with which Martian samples can be compared in the search for life.

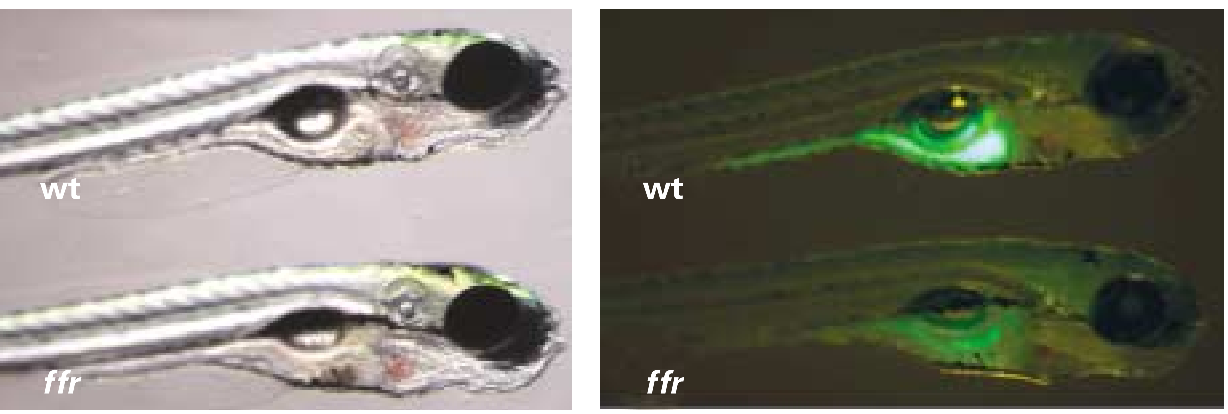
*The research was part of the Arctic Mars Analogue Svalbard Expedition (AMASE). Researchers come from the following institutions: Physics of Geological Processes, University of Oslo (lead institution); Geophysical Laboratory and Department of Terrestrial Magnetism, The Carnegie Institution of Washington; NASA Jet Propulsion Laboratory; University of Leeds; University of Oxford; Universidad de Burgos, Spain; The Smithsonian Institution; Penn State University; Geological Institute, University of Oslo; and Idaho National Laboratory.

Much of the work reported on was supported by the NASA Astrobiology Institute (NAI). NAI, founded in 1998, is a partnership between NASA, 16 major U.S. teams, and six international consortia. NAI's goal is to promote, conduct, and lead integrated multidisciplinary astrobiology research and to train a new generation of astrobiology researchers. For more information about NAI, visit http://nai.nasa.gov/.

Gene Mutation Causes Lethally Low-Fat Diet

"The fact that just one gene can have such a huge effect is encouraging, because it might reveal a means for treatment of human disease."

We are all familiar with the dangers of too much fat in our diet—increased risk of diabetes, heart disease, and obesity are just a few of the severest consequences. But some rare metabolic disorders, such as hypolipidemia and Tangier disease, seem to work in reverse by severely limiting the amount of fat and cholesterol that enters the bloodstream. Researchers from the Carnegie Institution, the University of Pennsylvania, and Thomas Jefferson University have found a specific gene that could be responsible for such conditions; when the gene is disrupted, so is the ability to absorb lipids—fatty substances that include cholesterol—through the intestine.



Zebrafish larvae with a lethal mutation affecting fat metabolism *(ffr)* look the same as normal larvae (wt) under normal magnification (left). However, when the embryos ingest lipid molecules labeled with a fluorescent tag (right), differences in fat metabolism become apparent. The normal embryos absorb the labeled lipids into their bloodstream, resulting in a fluorescent gut, while the mutants eliminate them, resulting in a darker gut.

(*Images courtesy Ho et al.,* Cell Metabolism.)

In their latest research, published in the April 4 issue of the journal *Cell Metabolism*, Steve Farber of Carnegie's Department of Embryology and Michael Pack of the U. Penn School of Medicine describe their efforts to locate a gene called *fat free* within the genome of the zebrafish. These fish have become popular research subjects because their embryos are transparent, which allows developmental studies that cannot be done with traditional lab animals such as mice and rats. Farber and Pack found that, despite the distant evolutionary relation between humans and zebrafish, the *fat free* gene in zebrafish is quite similar to a pair of human genes.

The researchers also explored the physical effects of a specific mutation of the gene, seeking to explain why larval fish with the mutation have trouble absorbing cholesterol. These fish die when they are less than two weeks old, even though they look normal and swallow properly. "There is a lot we still don't know about how animals absorb, transport, and otherwise manage lipids," Farber said. "The fact that just one gene can have such a huge effect is encouraging, because it might reveal a means for treatment of human disease."

Farber and Pack began by looking for structural defects in the mutants' digestive organs. The zebrafish have abnormalities in the liver cells and ducts that produce bile—a salty, somewhat soapy fluid that helps lipid digestion. Certain cells in the pancreas are also flawed, interfering with the production of digestive enzymes necessary for the breakdown of lipid molecules.

Importantly, the mutants also have defects in the cells that line the intestine, where fat and cholesterol absorption takes place. Normally, globules of lipid pass into these cells in small sacs called vesicles. These vesicles connect with the Golgi apparatus, a labyrinth of membranes filled with enzymes that modify the fats, and then new vesicles transport the fats out of the cell and into the bloodstream. In *fat free* mutants this process doesn't work properly, and many lipids never reach the bloodstream; as a result, the animal is deprived of vital fats and cholesterol.

Farber and Pack used a genetic strategy called positional cloning to locate *fat free* in the zebrafish genome and to determine its sequence. The results suggest that the gene shares 75% of its sequence with a human gene called ANG2 (Another New Gene 2), which so far has no known function. It also shares parts of its sequence with a gene called COG8, which is known to affect the Golgi apparatus. A change in only one base—one "letter" in the DNA code—is responsible for the lethal *fat free* mutation in zebrafish. "This gene is absolutely necessary for cholesterol absorption—without it, the animals die," Farber said.

This finding is encouraging to Pack, who points out that "if we can understand this process in zebrafish, perhaps we can take what we learn and apply it to similar genes in humans, which could in turn lead to treatment for lipid metabolism disorders."

—BY MATTHEW EARLY WRIGHT

Additional support was provided by grants from the American Heart Association, the National Institutes of Health, and the Pew Scholars Program.

(Image courtesy NREL.)

Gas pumps that offer biofuels, such as this one (above) in Santa Fe, New Mexico, are cropping up around the country. "B20" is a diesel mixture that contains 20% biodiesel, and "E85" and "E10" are gasoline mixtures that contain 85% and 10% ethanol, respectively. B20 and E10 can be used in standard diesel or gasoline engines, but E85 can only be used in specially designed "flex fuel" vehicles (FFVs) that can run on any blend of E85 and unleaded gasoline.

Giant hybrid *Miscanthus* (*Miscanthus x giganteus,* below) could prove to be a valuable feedstock for biofuels. A perennial grass that requires very little water, fertilizer, and pesticide, *Miscanthus* can yield up to 26 tons of dry biomass per acre—more than eight times the biomass yield of corn stover. Because it grows from established roots and not from seed, it has a longer growing season than annual feedstock crops such as corn.

(Image courtesy John D. Caveny, ECCL.)

Growing Solutions to the Energy (and Climate) Crisis

At the end of the 1985 sci-fi comedy *Back to the Future*, mad scientist Dr. Emmett Brown returns from 2015 and frantically grabs some banana peels to refuel his time machine—a heavily modified DeLorean that required weapons-grade plutonium earlier in the film. The scene deftly hints at a future, now closer to our present, in which the world finds creative and surprising solutions to its energy woes.

Unfortunately, today's reality does not inspire such optimism. The United States is particularly dependent on—some say addicted to—petroleum, a limited resource with a steeply climbing economic and political price tag. More critically, the burning of oil and other fossil fuels releases greenhouse gases that contribute to global warming. At present, many "clean" and renewable energy sources such as wind turbines, hydroelectric dams, and solar cells account for a pitifully small wedge of the energy pie.

Chris Somerville, director of the Department of Plant Biology, refuses to entertain such pessimism. As he sees it, a solution to our energy and climate crisis is waiting in the soil at our feet. By cultivating plants—nature's own solar cells—and processing them to create fuel, Somerville believes we can harness enough of the 90,000 trillion watts of solar energy that strikes the Earth's surface each day to make petroleum addiction a distant memory.

As Somerville articulated in his May Carnegie Evening lecture, a plant-based energy economy could also slow or stabilize global warming. Greenhouse gases that plant-derived biofuels release as they burn can be offset by carbon dioxide that biofuel crops absorb as they grow. If production is closely matched with consumption, this strategy could result in a "carbon-neutral" closed loop of carbon dioxide emission and absorption.

"The only real driver for biofuels is to mitigate global climate change," Somerville says. "We could, in principle, deal with the strategic issues of petroleum dependency by turning to coal, but that would carry a great cost in terms of global carbon dioxide emissions."

BOTTLING THE SUN

The idea of using plants for energy is not new; humans heated their homes and cooked their food using wood fires centuries before anyone knew how to get coal and petroleum out of the ground. Today, about 10% of the world's energy comes from biomass.

Plant parts can be turned into liquid fuels, including ethanol and biodiesel. This isn't a new idea, either; Henry Ford considered fueling the Model T with ethanol, and Rudolf Diesel reportedly powered his first eponymous engine with peanut oil. But petroleum fuels won out over biofuels early in the 20th century, mainly because they could be extracted and refined at lower cost. However, a lot has happened in the last hundred years.

[Continued on page 10]

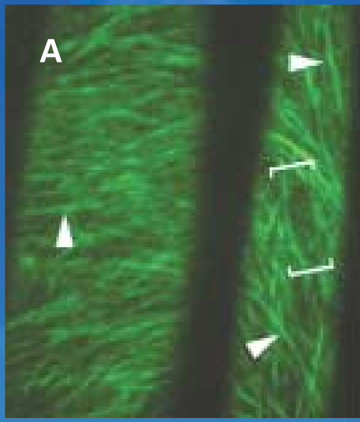
[Continued from page 9]

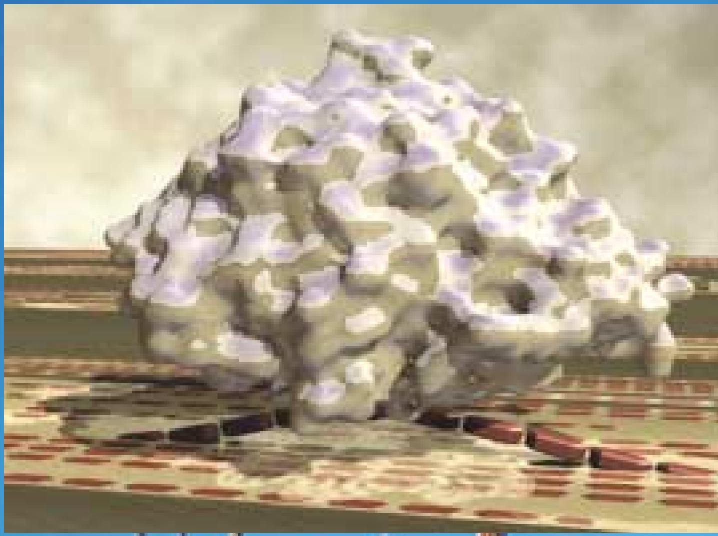
"Biofuels are alive and well in the United States today," Somerville explains. "Many production facilities are scattered around the country, and more are scheduled to be built. Thanks to technical advances, ethanol in particular is becoming cheaper and easier to produce with time. In fact, it is already cost-competitive with gasoline at today's prices."

Today, most of the ethanol produced in the U.S. comes from the kernels of corn plants. Golden nuggets of corn are packed with starch that can be broken down into sugar, which in turn can be fermented to make ethanol. But in terms of total biomass, the process uses relatively little of the plant; the stalks, leaves, and bare cobs—collectively called stover—are largely made of fibrous molecules such as cellulose that are not easily converted to fuel.

It is not impossible to squeeze energy from cellulose, however. Chemically speaking, starch and cellulose are closely related: both are essentially long chains of the sugar glucose and differ only in the bonds that link them. This subtle difference renders cellulose extremely difficult to break down. But some bacteria and fungi feed on plant fibers and produce cellulose-chomping enzymes called cellulases. Biofuel researchers are taking their cues from these organisms to free up valuable plant sugars.

Molecules of cellulose synthase, the enzyme that produces cellulose, follow microtubule "tracks" in growing plant cells. Cellulose synthase (green, panel A) and tubulin (red, panel B), the protein that makes up microtubules, are highly correlated, especially in the areas marked with arrows. Very little of either molecule is found inside the area marked with brackets. The third image (panel C) shows both panels superimposed on each other.



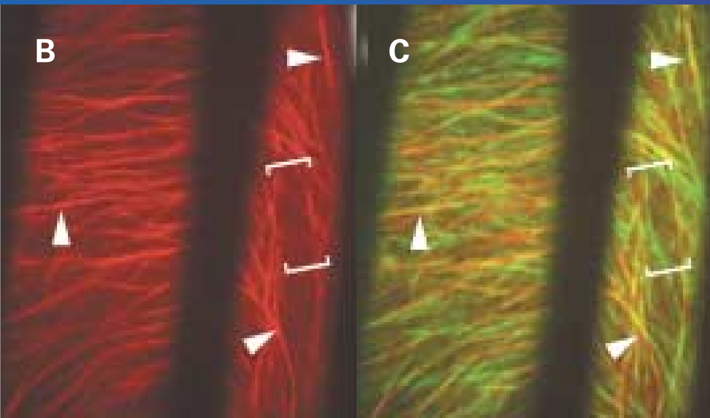


ROOM TO GROW

Cellulose is the most abundant plant-made molecule on Earth. It is a major component of plant cell walls, where it weaves a framework with two other molecules, hemicellulose and lignin. These molecules get in the way of cellulase, making it harder for the enzyme to do its job. Moreover, individual chains of cellulose are clumped in tightly packed fibers that resemble a taut rope. These features serve a useful purpose—to strengthen the plant's body and to help protect it from infection and parasites—but they are a roadblock to biofuel researchers.

Deciphering cellulose's role in this complex structure is Somerville's main research focus. Earlier this year he and David Ehrhardt, also of Plant Biology, made the first real-time observations of cellulose fibers forming. The research gave the first clear evidence that cell wall construction might be guided by an array of protein fibers—called microtubules—that help to shape growing plant cells. "The more we understand about cellulose, the easier it will be to modify it," Somerville says.

At one time, acid solutions were the only practical way to break down cellulose in the lab. In the last decade, however, cellulase enzyme technology has grown by leaps and bounds. Further reducing the production cost of enzymes remains a major focus of biofuel research. "It used



(Image used with permission of the American Association for the Advancement of Science.)

Efficient cellulases—enzymes that can break down cellulose—are important for biofuels research. Some cellulases (left) pry strands of cellulose (chains of brown blocks) from the board-like surface of a fiber to pop off sugars (individual brown blocks) one at a time. More-efficient cellulases, such as this one (below) isolated from the fungus *Trichoderma reesei*, have a subunit (the small clublike appendage) that holds on to the cellulase strand, making it easier for the enzyme to break off multiple sugars.

(Images courtesy Mike Himmel, NREL/DOE Biomass Program.)

to cost $5 a gallon just for the enzymes required to make ethanol from cellulose," Somerville says. "But prices have dropped as much as tenfold within just the last two years. Engineering these enzymes is extremely important."

Equally important is the development of biomass crops—called feedstocks—that are grown specifically for making biofuels. In principle, anything that contains cellulose can serve as a feedstock, including wood chips and used cardboard, among others. But Somerville believes that dedicated biofuel crops can provide a more reliable, easily manipulated supply of biomass.

Giant perennial grasses, such as switchgrass and *Miscanthus*, are the newest darlings of feedstock researchers. Because they regrow from established, nutrient-storing root systems every season instead of growing from seed, they require much less fertilizer and pesticide. They also have a significantly longer growing season than annual crops like corn, and produce more biomass. For example, an acre of corn will yield an average of 3 tons of stover, but an acre of giant hybrid *Miscanthus* (*Miscanthus* x *giganteus*) can yield up to 26 tons of dry biomass, even without irrigation. "*Miscanthus* is my new favorite plant," Somerville says with a smile.

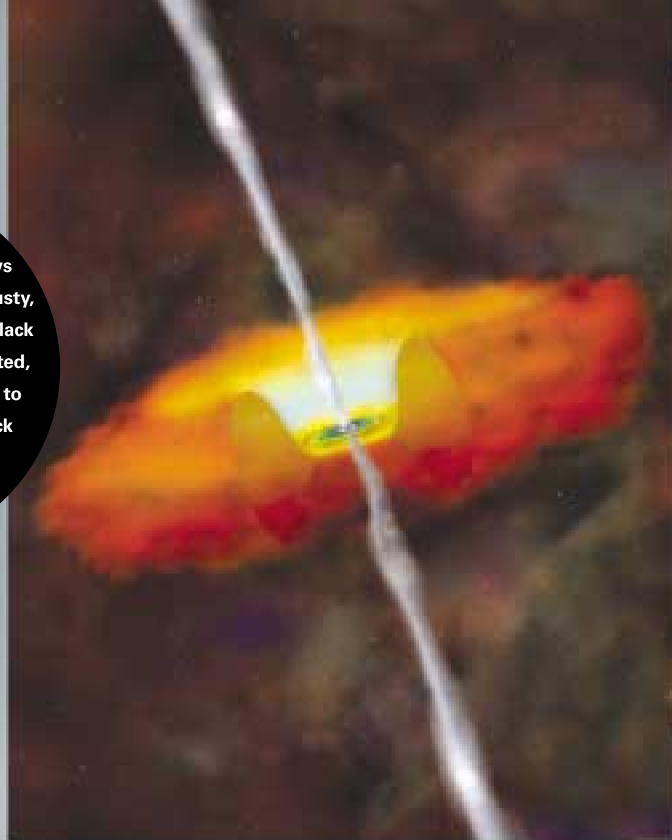
BACK TO THE FUTURE

At least in the near term, Somerville believes ethanol will play a particularly important role on the world's energy stage. But he envisions a future where other compounds, such as the alkanes that make up petroleum fuels, will also be derived from plants. "In 15 years, we won't have an ethanol economy, but a hydrophobe economy," he predicts, referring to the broad class of chemicals that alkanes belong to. "We are in a transitional phase now, and ethanol may prove to be an effective bridge. The issue now is not so much technology, but infrastructure. People are reluctant to invest until they know what process we will use."

The issue doesn't seem to be one of supply, either. According to a 2005 report issued jointly by the Department of Energy and the Department of Agriculture (commonly cited as the Billion-Ton Vision), 1.3 billion dry tons of biomass per year are available right now. With current technology, this could be converted into 100 billion gallons of fuel ethanol, if the production capacity existed.

As tons of carbon dioxide spew into the air every year, it is easy to despair for the world's climate. But optimists like Chris Somerville have risen to the challenge by advocating the benefits of renewable, plant-based biofuels that can help recycle atmospheric carbon dioxide. We might not be powering our DeLoreans with banana peels anytime soon, but nevertheless, our energy future is as bright as the Sun.

—BY MATTHEW EARLY WRIGHT



This artist's conception shows a black hole surrounded by a dusty, gaseous accretion disk. Since black holes can not be directly detected, astronomers study such disks to determine the masses of black holes and other features of their environment.

Propelled by the energy of its central black hole, this Seyfert galaxy, Circinus, shoots gas into space.

Carnegie astronomer Luis Ho has been at the Carnegie Observatories since 1998.

Hunting for Black Holes

Churning, seething matter is sucked into oblivion by the most powerful force in the universe—a black hole. These kings of consumption are unimaginably dense areas made by coalescing matter at galactic centers, or by the collapse of massive stars at the end of their lives. Their gravitational attraction is so fierce, not even light can escape. As the surrounding material is whipped into a frenzy, it radiates across the electromagnetic spectrum—from radio to X-rays. Although black holes can't be seen, the heat from this turbulence can be, and it is detected and analyzed by astronomers like the Observatories' Luis Ho.

"When I was an undergraduate, studying philosophy and physics, I heard a popular talk that our own Galaxy, the Milky Way, contains a 3-million-solar-mass black hole at its center . . . That got me hooked on astronomy," he reflected. Today, Ho is drawn to bulges, the central portions of galaxies where black holes make their mark. At the Observatories since 1998, he has been trying to understand how prevalent black holes are, how many varieties exist, how their unimaginable energy swirls stars, gas, and dust around their central accretion disks, and ultimately what the relationship is between black holes and galaxy evolution.

Analyzing the Invisible

To look at the behavior of the material in the central disks that surround these cosmic gluttons, Ho and colleagues marshal an arsenal of ground-based and space-based telescopes to home in on active galactic nuclei—galaxy centers that produce more energy than can be explained purely by their quantity of stars, and that emit this energy in characteristic spectral patterns. Several galaxy types are known to have active galactic nuclei. These include quasars, the brightest objects in the Universe; Seyfert galaxies, disk galaxies with very bright centers consisting of especially hot, fast-moving gas; radio galaxies, giant elliptical galaxies with bright centers detected at radio wavelengths; and LINERs, galaxies that look normal, but whose emissions are not representative of young stars.

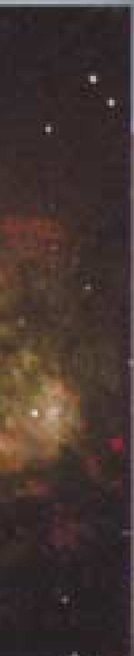
Ho can tell if a galaxy harbors a black hole by measuring the radiation output at its center across the electromagnetic spectrum. Weaker black holes emit less overall energy than do strong ones. He gleans other features of these mystifying objects by developing unique computational methods and analyzing chemical and dynamic features of the surrounding stars, gas, and dust. In the last decade, his team has yielded an impressive array of celestial surprises.

How Many and How Big?

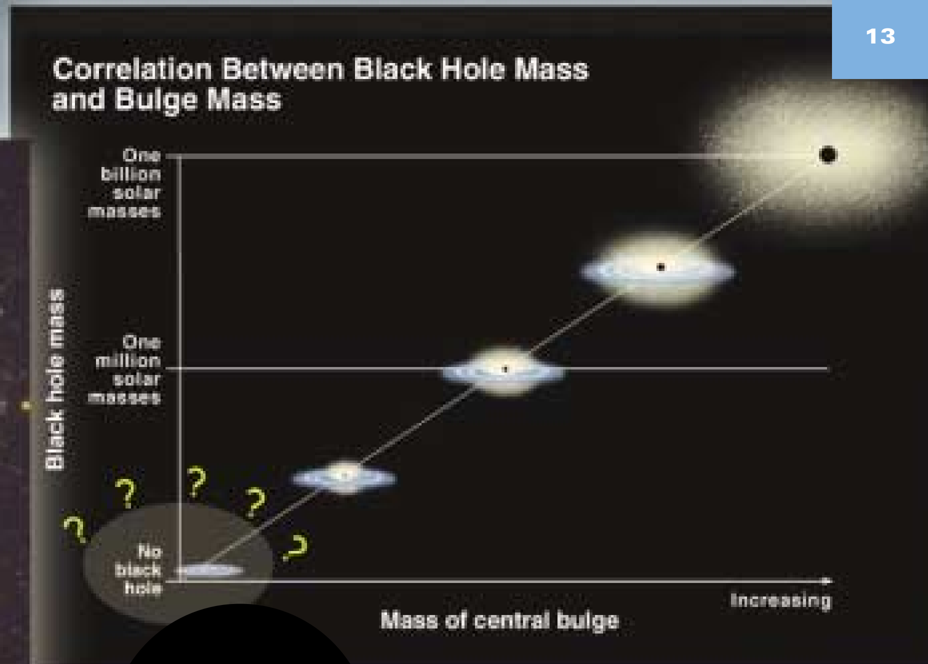
Until the late 1990s, it was generally believed that black holes were rare. Ho decided to test this notion. He surveyed an unprecedented 500 galaxies as part of his dissertation research at Berkeley, completing the most definitive black hole census yet for nearby galaxies. His results upended the prevailing notion. Ho found that most galaxies have at least weakly active nuclei and thus contain black holes.

Next, Ho and colleagues embarked on determining the masses of these celestial powerhouses, again by looking to the central bulge. The Milky Way is a common spiral with a medium bulge and a 3-million-solar-mass black hole. Large ellipticals—galaxies that probably formed from galactic mergers—and early-type spiral galaxies also have bulges, but late-type spirals and tiny dwarf galaxies do not.

Over several years, the scientists measured the velocity of the stars and gas that swirl around the centers of about 30 nearby galaxies to determine black hole masses. "It's much the same way we can determine the mass of the Sun by measuring how fast the planets move around it," he explained. To probe very close to the galaxy centers they



The collection of old stars at center is a globular cluster (G1). It is located in the nearby Andromeda galaxy. Ho and colleagues found that G1 houses a black hole that is about 20,000 times the mass of the Sun.



Ho's team found that the larger the galactic bulge, the more massive the black hole.

Images from left to right, courtesy of Luis Ho; Harvard-Smithsonian Center for Astrophysics and NASA; Space Telescope Science Institute and NASA; Space Telescope Science Institute and NASA; Luis Ho.

had to use the highest resolution telescope available—the Hubble Space Telescope. "We found the telltale signature of a black hole—stars and gas swirling around a central dark object—in *every* galaxy we looked at," he said. Their masses ranged from a few million to a few billion Suns. "Equally astonishing, we found that the mass of the black holes directly scaled with the mass of the galaxy's bulge—the larger the bulge, the more massive the black hole. Black hole formation has to be intimately coupled with the formation of the bulge. This result has galvanized a whole industry overnight."

Past Their Prime

The largest, supermassive black holes have masses that range from millions to billions of Suns. Ho's group found that some of these not-so-gentle giants are consuming much less material now than they did billions of years ago, when they devoured so much matter that they radiated as quasars—shining with the light of over a trillion Suns. The evidence comes from measuring and modeling their spectra—from radio to X-rays. The team found that black holes with low radiation are on a diet.

They also discovered that the disks of these fading black holes look different from those of their more robust counterparts. Hefty black holes have pancake-like disks, while the central structures of weakened black holes resemble doughnuts. "The puffy doughnuts tend to expel material along the poles, making outflows or jets," Ho said. He thinks that this process might be linked to the way accreting black holes generate radio jets—a process that has been a mystery for almost 50 years.

How Small Can They Be?

Although all bulges seem to contain black holes, it is less certain whether a bulge is required to house a black hole. Ho, along with Jenny Greene of the Harvard-Smithsonian Center for Astrophysics and Aaron Barth of the University of California, Irvine, wanted to see if bulgeless galaxies—the smaller systems that make up the bulk of the galactic population—do, in fact, lack black holes.

The team reasoned that if black holes are found in bulgeless galaxies, they would probably be smaller than those found in galaxies with bulges. They suspected that these intermediate-mass black holes are quite rare today. Ho believes that these black holes were more common in the past and could be the "seeds" of their supermassive cousins. Since current technology cannot directly detect these smaller objects, except among a few of our nearest neighbors, the astronomers decided to pore over previously collected data from nearby galaxies to look for an elusive signal. They figured that small galaxies with intermediate-mass black holes should glow as miniquasars, radiating tremendous energy as surrounding matter is engulfed. They uncovered the telltale signal confirming an entirely new population of these objects—intermediate-mass black holes, with masses between 10,000 and 1 million Suns.

The discovery of these new, smaller galactic black holes may help decipher the origin of their heavier counterparts. Ho believes that intermediate black holes should 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.

Even Smaller?

In 2002, Ho and collaborators reported finding a black hole, of about 20,000 solar masses, in a collection of old stars known as a globular cluster in the nearby Andromeda

[Continued on page 14]

[Continued from page 13]

galaxy some 2.2 million light-years from Earth. This was one of two discoveries made at about the same time that represented yet another entirely new class of black holes—perhaps an additional clue in the evolution of these enigmatic objects.

This plethora of discoveries has propagated a growing body of questions about black holes. To consolidate the latest on the growing body of research, Ho organized an international symposium on the subject as part of the centennial celebrations of the Carnegie Observatories. He brought together experts conducting different but interrelated research to better understand how black holes and galaxies are intertwined; the talks are published in volume 1 of the *Carnegie Observatories Astrophysics Series.* Ho will present the very latest on the mysteries of black holes on May 10, 2007, at the Carnegie Capital Science Evening at the administration building in Washington, D.C. (See page 20 for details.)

Oceans May Soon Be More Corrosive Than When the Dinosaurs Died

Coral reefs, such as this one, are especially susceptible to damage from increased ocean acidity.

Sixty-five million years ago, a catastrophe of global proportions—possibly the aftermath of a colossal meteorite impact—wiped the dinosaurs from the face of the Earth. But they were not the only casualties; fossil records also reveal a massive die-off of corals in the world's oceans, most likely the result of a drastic shift in ocean chemistry.

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

Using computer models, Ken Caldeira of the Carnegie Institution's Department of Global Ecology has predicted that the oceans will become far more acidic within the next century. He has found some startling similarities between these data and evidence of ocean chemistry from the fossil record. These connections offer a glimpse of what the future could hold for ocean life if society does not drastically curb carbon dioxide emissions.

"The geologic record tells us the chemical effects of ocean acidification would last tens of thousands of years," Caldeira said. "But biological recovery could take millions of years. Ocean acidification has the potential to cause extinction of many marine species."

When carbon dioxide from the burning of coal, oil, and gas dissolves in the ocean, some of it becomes carbonic acid. Over time, accumulation of this carbonic acid makes ocean water more acidic. When carbonic acid input is modest, sediments from the ocean floor can buffer the increases in acidity, but at the current rate of input—nearly 50 times the natural background from volcanoes and other sources—this buffering system is overwhelmed. Previous estimates suggest that in less than 100 years, the pH of the oceans could drop by as much as half a unit from its natural value of 8.2 to about 7.7. (On the pH scale, lower numbers are more acidic and higher numbers are more basic, or alkaline.)

This drop in ocean pH would be especially damaging to marine animals such as corals that use calcium carbonate to make their shells. Under normal conditions the ocean is supersaturated with this mineral, making it easy for these creatures to grow. However, an increasingly acidic ocean would dissolve calcium carbonate more easily, putting these species at particular risk.

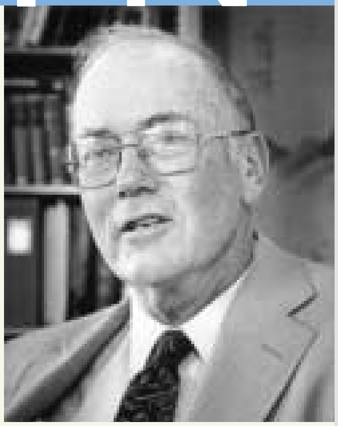
The last time the oceans endured such a drastic change in chemistry was roughly 65 million years ago. Though Caldeira does not know exactly what caused this ancient acidification, he is confident that it was directly related to the cataclysm that annihilated the dinosaurs. The fossil record reveals a precipitous drop in the number of calcium carbonate-shelled species, especially corals and plankton, in the upper ocean at this time. This pattern of extinction is consistent with the effects of drastically acidified seawater. During the same period, species with shells made from resistant silicate minerals were more likely to survive.

The world's oceans came close to an acidic catastrophe about 55 million years ago, when the temperature of the Earth spiked and large amounts of methane and/or carbon dioxide flooded the atmosphere. There is no evidence, however, that this caused a mass extinction event.

"Ultimately, if we are not careful, our energy system could make the oceans corrosive to coral reefs and many other marine organisms," Caldeira cautions. "These results should help motivate the search for new energy sources, such as wind and solar, that can fuel economic growth without releasing dangerous carbon dioxide into the environment."

—BY MATTHEW EARLY WRIGHT

IN Brief



❶ Carnegie trustee emeritus Charles H. Townes, winner of the 2006 Vannevar Bush Award

❷ Carnegie trustee and recipient of the Centennial Medal of the Harvard University Graduate School of Arts and Sciences Sandra Faber

Trustees and Administration

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

—

❷ Carnegie Institution trustee and University of California, Santa Cruz, University Professor of Astronomy and Astrophysics **Sandra Faber** was awarded the Centennial Medal of the Harvard University Graduate School of Arts and Sciences June 7. She was also elected to the Harvard Board of Overseers. Faber has been a Carnegie trustee since 1985. The Centennial Medal recognizes contributions to society resulting from graduate education at the university. After receiving a B.A. in physics from Swarthmore College, she pursued her Ph.D. in astronomy at Harvard, which she received in 1972. Much of her dissertation work was conducted at the Carnegie's Department of Terrestrial Magnetism in Washington, D.C.

—

❸ The new Rose Center, to house the Yale University Police Department and community center, was formally dedicated May 30. The facility was named for Carnegie trustee **Deborah Rose**, the "cornerstone" donor.

—

Carnegie president **Richard Meserve** made introductory remarks at the Astrobiology Science Conference in Washington D.C., Mar. 26. He was moderator of the session "Energy, Security, and the Long War of the 21st Century" at a meeting at MIT of the National Academies' New Government-University Partnership for Science and Security on May 15-16. On June 2, Meserve made a presentation on nuclear safety matters at a symposium in Tokyo, Japan, sponsored by the Japan Atomic Industrial Forum. On June 21, he moderated a panel at an LNG Forum sponsored by the National Commission on Energy Policy. He attended a meeting of the Advisory Council of the Princeton Plasma Physics Laboratory in Princeton, NJ, on June 22.

—

After 13 years as financial accountant, **Trong Nguyen** moved to the Geophysical Lab as assistant comptroller. **Heather Davis** and **June Napoco-Soriente** have joined the administration as financial accountants. **Claire Hardy**, formerly in the office of advancement, is now technical secretary at GL.

The Maxine F. Singer Building was host to the Mid-Atlantic Regional Developmental Biology Conference May 5 and 6. The meeting, which had over 140 participants from universities and medical schools, was organized by staff members Steven Farber and Alex Bortvin, and Mark Van Doren of Johns Hopkins. The meeting began with an educational workshop for local teachers led by Farber. Two prominent biologists, Arthur Lander and Ruth Lehmann, gave keynote lectures. Additionally, 24 speakers and over 40 poster platform presenters discussed their work in developmental biology. The program can be viewed at http://www.ciwemb.edu/midatlantic2006/.

Embryology

Don Brown gave the keynote address at the 39th Annual Meeting of the Japanese Society of Developmental Biologists in Hiroshima June 2.

—

On May 10 **Joe Gall** gave the 30th Annual Mac V. Edds Lecture in the Dept. of Molecular Biology, Cell Biology, and Biochemistry, Brown U.

—

After receiving his Ph.D. from U. Tokyo, **Kotaro Hama** joined the Farber lab as a postdoctoral fellow in Apr. He is exploring the mechanisms by which lipids in the yolk are transferred to zebrafish embryos and the cell biology of intestinal lipid absorption and function.

—

Hongjuan Gao joined the Gall lab in Feb. as a postdoctoral fellow to work on the structure of the cell nucleus in *Drosophila*. Two undergraduates, **Ellen Kutzer** from Washington College and **Matthew Peters** from George Washington U., joined the Gall lab for the summer.

—

Christine Murphy has taken a position at the new Janelia Farm research facility of the Howard Hughes Medical Institute. She was a senior technician for 23 years with Joe Gall.

—

(Image courtesy Yale Bulletin.)

❸ Carnegie trustee Deborah Rose cuts the ribbon for the new police department and community center facility that bears her name at Yale.

Johns Hopkins undergraduate **Allisandra Wen** in the Halpern lab received a Howard Hughes Summer Research Fellowship for her work on zebrafish forebrain development. Ph.D. students **Lori Orosco** and **Robyn Goodman** won awards for excelling as laboratory teaching assistants from the Johns Hopkins Biology Dept.

—

Zhonghua Liu joined the Yixian Zheng lab as postdoctoral fellow in Apr. to work on understanding how the cell nucleates and organizes microtubules to achieve intracellular organization and cell division.

—

After almost 30 years as the Embryology director's administrative assistant, **Pat Englar** retired Jun. 30 to move to FL.

Geophysical Laboratory

Bjørn Mysen and former postdoctoral fellow **Pascal Richet** received the George W. Morey Award in May from the American Ceramic Society for their groundbreaking book *Silicate Glasses and Melts: Properties and Structure*. The award is the most prestigious honor given by the glass community. Morey is a former GL staff member.

—

Wendy Mao, former CDAC-sponsored student and currently an Oppenheimer Fellow at LANL, is the 2006 recipient of the APS Rosalind Franklin Award honoring young investigators. See http://www.aps.anl.gov/News/APS_News/2006/20060417.htm for more information.

—

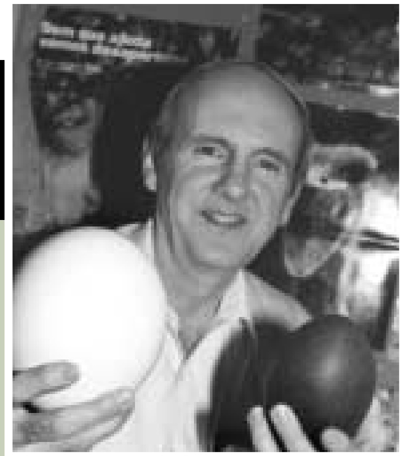
In Mar. **George Cody** presented a lecture on the hydrothermal origins of life at the AbSciCon 2006 meeting in Washington, DC. The talk was highlighted in *Science* magazine. In Apr. Cody participated in a short course on the origins of life at Stockholm U.

—

Robert Hazen lectured on *Genesis: The Scientific Quest for Life's Origin* on CSPAN-II Book TV and lectured on origins of life research at Franklin and Marshall U. and at the Astrobiology Science Conference in Washington, DC.

—

▼ William Watson and Nahathai Srivali, seniors at Baltimore Polytechnic Institute, are pictured after competing in the 51st Annual Baltimore Science Fair held Mar. 25-26 at Towson U. Srivali won the grand prize for her research in the Spradling lab analyzing *Drosophila* gene expression in living animals. Watson won second prize for his studies in the Halpern lab of the zebrafish androgen receptor gene. Srivali advanced to the International Science Fair held in Indianapolis on May 7-13.



GL'S PETER EDGAR HARE DIES

Peter Edgar Hare died on May 5 at the Port Orange Christian Adult Care Home after a long battle with Lyme disease. Hare was involved in searching for signs of life on the first rock samples returned from the Moon. He was born on April 14, 1933, in Maymyo, Burma, where his parents were missionaries for the Seventh Day Adventist Church. He attended Pacific Union College in Angwin, California, where he received his B.S. in chemistry. One year later, he earned an M.S. from UC-Berkeley and went on to teach chemistry at Pacific Union. He then went to Caltech to study for his Ph.D. His dissertation was on the amino acids and proteins from carbonate minerals found in the shells of modern and fossil mussels (*Mytilus californicus*), research that was published in *Science* magazine in 1963.

This work attracted the attention of GL director Philip H. Abelson, and Hare was invited to join the scientific staff in 1963. During his early years, he set up a new instrument to measure amino acids. He developed a new methodology for amino acid analysis, which was showcased at the Federation of the American Society for Experimental Biology in 1966.

In 1968 Hare and Abelson published the first paper on the discovery of left- and right-handed amino acids in fossil shells. Living organisms are composed almost exclusively of left-handed amino acids. After an organism dies, the left-handed amino acids convert to right-handed amino acids, a process that Hare used to accurately date ancient shells and bones. His work for the remainder of his career centered on this conversion, called racemization, and exploiting it for dating early man in North America, early human evolution in Africa, and the geological progression of Arctic climates.

When the first Moon rocks came back to Earth, Hare was involved in searching for signs of life on them. He published his findings in *Science* in 1971, indicating that there was some evidence for amino acids in the lunar samples, but that they were probably from terrestrial sources. By that time, Hare's laboratory had become the training ground for young scientists from paleontology, geochemistry, archaeology, and biochemistry. In 1979 he published a landmark methods paper on new techniques for measuring the left- and right-handed amino acids. Hare and his coauthor and coinventor Emanuel Gil-Av of the Weizmann Institute of Science in Israel obtained a patent on their invention.

Hare is survived by his wife, Patti, and two children, Carol Pack of Laurel, MD, and Calvin Hare of Orlando, Florida; three grandchildren and a brother.

Russell Hemley was invited to the speak at the Workshop on Synergy of 21st Century High-Pressure Science and Technology in Argonne, IL, cosponsored and coorganized by CDAC, beginning Apr. 29. On June 4-8 he attended ICOPS 2006 in Traverse City, MI, and gave an invited talk, "Emerging Diamond Technology and the Science of Extreme Conditions."

—

In Feb. **Razvan Caracas** participated in the workshop "Fundamental Physics of Ferroelectrics, 2006" in Williamsburg, VA, with a poster about new, exotic ferroelectrics. In Mar. he gave a talk at the APS March Meeting 2006 in Baltimore about materials with post-perovskite structure. He also gave an invited talk at the GSA NE Meeting in Harrisburg, PA, on the study of Earth's lower mantle and the D" layer.

—

Alexander Gavriliuk from the Institute for High Pressure Physics, Russia, worked with Viktor Struzhkin in Apr. and May.

—

Liwei Deng has been appointed a predoctoral research associate beginning Sept. 1 to work with Yingwei Fei on thermal equations of state. Deng is from the Institute of High Pressure and High Temperature Physics, Southwest Jiaotong U., China.

—

Steve Jacobsen is now on the faculty of the Dept. of Geological Sciences at Northwestern U.

—

Former CDAC summer undergraduate high-pressure intern **Andrea F. Young** was the first author on a paper in *Physical Review Letters*, "Synthesis of Novel Transition Metal Nitrides IrN_2 and OsN_2." See http://cdac.gl.ciw.edu/content/view/144/1/.

—

GL welcomed two additional business office members: **Trong Nguyen,** from the Carnegie administration, and **Phil Davis**, accounts payable specialist from the accounting department of the U.S. Mint.

Global Ecology

Department director **Chris Field** is among those involved in an amicus brief submitted in the Supreme Court case in which Massachusetts is suing the EPA over its refusal to regulate greenhouse gases. The brief explains what is known about climate change and its impacts. Field traveled to Canberra, Australia, in Mar. to review the CSIRO Division of Land and Water. He gave seminars at Cornell U. in Apr. and at the John Innes Center in Norwich, UK, in May.

—

Greg Asner, **Robin Martin**, **Kim Carlson**, **Natalie Boelman**, and **Maoyi Huang** work in HI studying the impacts of climate variability and invasive species on carbon and hydrological dynamics in Hawaiian rain forests. They also are investigating ways to combine aircraft and satellite remote sensing data with field measurements for biodiversity assessments.

—

The Asner lab's "Brazil group" is analyzing forest damage caused by selective logging throughout the Brazilian and Peruvian Amazon forests. On Mar. 13 **Greg Asner** and **Paulo Oliveira** traveled to Peru to kick off the new Amazon forest disturbance and logging project. In May Asner and **David Knapp** traveled to the Brazilian Cerrado savanna region to study vegetation drought stress in conjunction with satellite imaging. Asner also gave an environmental science seminar at Duke U.

—

Workshop on Synergy of 21st Century High-Pressure Science and Technology

The High Pressure Collaborative Access Team (HPCAT) hosted the Workshop on Synergy of 21st Century High-Pressure Science and Technology at the Advanced Photon Source (APS), Argonne National Laboratory. It was jointly sponsored by COMPRES and CDAC. One hundred twelve scientists, including 20 graduate students and postdoctoral researchers, attended. The aim of the workshop was to review the status of U.S. high-pressure research and to identify future grand challenges in nine areas: integrated high-pressure science, dense condensed-matter physics, chemical bonding under compression, high-pressure materials research, high-pressure petrology and mineralogy, deep earth geochemistry, Mission to the Earth's Core, high-pressure seismology and elasticity, and biological and organic systems under pressure.

Experts gave 59 talks on the surge of recent high-pressure discoveries in these fields as well as the technological advances in instrumentation and analytical probes. Integration of state-of-the-art high-pressure techniques, facilities, and probes was proposed to meet future challenges for high-pressure research in multidisciplinary high-pressure fields in the 21st century. The consortium would enable high-pressure specialists and nonspecialists alike to focus on specific scientific goals, which have been hindered by technical limitations. A series of visionary papers will be published in the *Proceedings of the National Academy of Sciences* to illustrate the synergetic nature of these interdisciplinary fields.

Organizers were Ho-kwang (Dave) Mao (Carnegie), Guoyin Shen (HPCAT), Wolfgang Sturhahn (APS), Yanbin Wang (GSECARS), and Russell J. Hemley (Carnegie). The local organizing committee was composed of Haozhe Liu and Veronica O'Connor (HPCAT), and Michael Lerche (APS).

❹ Global Ecology's Ken Caldeira

❹ In Feb. **Ken Caldeira** went to Heron Island in Australia's Great Barrier Reef to measure fluxes of calcium carbonate and organic carbon. The data will help provide the basis for a model that could predict how coral reefs respond to increased carbon dioxide and warmer temperatures. While there, Ken taught a class in the Stanford in Australia program. He also worked with Ove Hoegh-Guldberg of U. Queensland to help design mesocosm experiments that could produce data that would be most useful for developing predictive models. On Apr. 8 Caldeira gave a talk, "Carbon Sequestration: Is It Feasible?" at Yale U., Environmental Science Center. On Apr. 13 he spoke about weather and climate change on KQED Radio's *Forum* program. In May Caldeira visited the Hadley Centre in Exeter, England, to discuss using their coupled ocean/atmosphere model for simulations of past and future climate. He also discussed modeling carbon and oxygen isotopes in marine organisms with Harry Elderfield at Cambridge U. OECD invited Caldeira to Paris to address a subministerial group developing science and technology research policy regarding energy technology development. He visited the Institute Pierre Simon Laplace, where he gave talks on ocean acidification and the climate effects of forests. He also addressed the Oceans Caucus of the U.S. House of Representatives on the issue of ocean acidification.

—

Field lab's **David Kroodsma** has covered over 6,300 miles in his ride for the climate. As of mid-May he was in Panama.

—

Halton Peters (Field lab) traveled to Nairobi in Apr. as part of his contribution to the UNEP GEO3 project.

—

Jason Funk of the Field lab returned to New Zealand, where he is completing his thesis project on forest carbon sequestration on Maori lands. **Erica Simmons**, **Julie Allen**, and **John Juarez** joined the Field lab as summer field assistants.

—

Eben Broadbent of the Asner lab will begin the Ph.D. program at Stanford. He will be working jointly in the Asner and Field labs.

—

Kim Carlson left the **Asner lab** in June to attend Yale U. **Matthew Jones** joined the **Asner lab** as a technician in June.

—

Larry Giles of the **Berry lab** was in Mali in Feb. installing a precision CO_2 monitoring station located on the southern edge of the Sahara Desert. This station will form part of the global CO_2 network that monitors the CO_2 balance of the atmosphere and assesses the net carbon balance of large regions. These stations will provide the first continuous records of CO_2 concentration in the atmosphere over Africa.

—

Roland Pieruschka of Germany's Forschungszentrum Juelich is working with Joe Berry at the Jasper Ridge Biological Preserve to test the laser-induced fluorescence transient (LIFT) instrument—a powerful technique for studying photosynthesis by individual leaves.

Observatories

On Apr. 12 **Wendy Freedman** gave an invited talk on "The Giant Magellan Telescope Project" at the 2nd Symposium on Astronomy, Cosmology, and Fundamental Physics, hosted by the Mitchell Institute at Texas A&M. She attended the premiere screening of Todd and Robin Mason's film *The Journey to Palomar* at Caltech on Apr. 19. On Apr. 20 Freedman joined Arnie Phifer, Carnegie board chairman Michael Gellert, and others at the MMT on Mt. Hopkins, AZ, for GMT fundraising. On Apr. 24 she gave an invited colloquium, "The Giant Magellan Telescope," at U. Chicago.

—

Alan Dressler, **Pat McCarthy**, **Ian Thompson**, and Magellan technical manager **Alan Uomoto** were awarded an NSF-TSIP (Telescope System Instrumentation Program) grant for $648,000 to provide a second, more sensitive Mosaic CCD Camera for IMACS on Magellan-Baade. The award also provides additional access to Magellan by the general astronomical community. The TSIP grant will fund the purchase of nine 2K x 4K E2V CCD detectors; the remaining cost of about $200,000 will be shared by the Magellan partners. The highly sensitive new camera will accelerate the study of distant galaxies and the early universe.

—

Luis Ho gave a talk on the GMT, visited Harvard U., and attended the NRAO Legacy Projects Workshop in Socorro, NM, and an NRAO Users Committee meeting.

—

The French Science Council invited **Barry Madore** for the final review of the HyperLEDA extragalactic database, held in Lyon on Apr. 3. On Apr. 20, as part of a lecture series by Carnegie astronomers at Pomona College, he led a seminar on the philosophical foundations of extragalactic astronomy. On May 16 he gave an invited talk in Heidelberg, Germany, "Women, Fire, and Dangerous Things: The Semiotics of Galaxy Morphology."

—

Patrick McCarthy spoke at the International Astronomical Union meeting, "Science with Extremely Large Telescopes," in Cape Town, South Africa, where he gave two talks. He also spoke at "Mapping the Cosmos" in Venice, Italy. McCarthy served on the NSF Program Review Panel for the National Optical Astronomy Observatories and on the Hubble Space Telescope Users Committee. He is on the scientific organizing committee for "Science with the Great Observatories" and spoke at the meeting of the American Astronomical Society in Calgary in June.

—

In Mar. **Andy McWilliam** spoke at a videocon at the Thirty-Meter Telescope (TMT) project office in Pasadena on "Water Vapor at Las Campanas Measured with the Magellan Echelle" for the GMT site survey. Other participants were from Las Campanas, CTIO, and Gemini from Chile, and a team from the UK. Also in Mar., he was on the NSF panel for Galactic Astronomy in Washington, DC. In May he was on an NSF site-visiting committee to the Joint Institute for Nuclear Astrophysics at Notre Dame U. He served on the Subaru telescope allocation committee (TAC) during the past year.

—

François Schweizer attended a conference on globular clusters at the Universidad de Concepción, Chile, where he presented an invited review. On May 2 he gave the last Carnegie lecture at the Huntington Library, Art Collections, and Botanical Gardens in San Marino, CA, titled "Colliding Galaxies and Their Cosmic Fireworks."

—

In Mar. **Steve Shectman** gave the annual Greenstein Lecture at Caltech, speaking on "Extremely Metal-Poor Stars." In Apr. he talked about the Giant Magellan Telescope (GMT) at five research institutes in the Netherlands.

—

Carnegie-Princeton Fellow **Inese Ivans** participated in the Sloan Digital Sky Survey and Sloan Extension for Galactic Understanding and Evolution (SDSS-II and SEGUE) meetings Mar. 23-28. Also in Mar., she was an invited lecturer for the 3rd Russbach Workshop on Nuclear Astrophysics organized by the Virtual Institute of Nuclear Structure and Nuclear Astrophysics and the Joint Institute of Nuclear Astrophysics in Russbach, Germany. She gave an invited seminar on Apr. 5 at the Nuclear and Particle Physics and Astrophysics Institutes, Ohio U. At Ohio State U. on Apr. 6, she gave an invited colloquium. She attended the NOAO Galactic Time Allocation Committee meeting in Tucson May 1-3, and participated in the NIC IX (Nuclei in the Cosmos-IX) Summer School at CERN, Geneva, June 19-23. She gave an invited talk on June 24 at the NIC IX Satellite Session on Nuclei in Globular Clusters.

—

Hubble Fellow **Jeffrey Crane** attended the SPIE conference "Astronomical Telescopes and Instrumentation" in Orlando in May, and presented his design work on the Carnegie Planet Finder Spectrograph.

—

Raul Jimenez (U. Penn.) spent six weeks in Apr.-May as a visiting scientist and presented a colloquium.

(Image courtesy MIT.)

❺ Merle A. Tuve Senior Fellow James Elliot of MIT

Plant Biology

Plant Biology director **Chris Somerville** presented a talk, "Mechanisms of Cellulose Synthesis," at the annual meeting of the Society for Industrial Microbiology in Nashville, May 1. He presented a keynote address, "The Future of Biofuels," at a symposium on renewable energy at U. Illinois on Apr. 14, and a talk with the same title as the keynote address at the Rick Symposium at UC-Davis on Mar. 15. He also presented the 2006 Carnegie Evening talk, "The Prospect for Meeting Our Energy Needs with Biofuels," on May 5 and at a meeting of the European Plant Biology Organization in Budapest, May 28.

—

Winslow Briggs gave a seminar at U. Missouri, "Phototropins: Photoreceptors with a Unique Photochemistry."

—

Shauna Somerville spoke at the Rick Symposium at UC-Davis on Mar. 15-16 and on Apr. 4-5 at the Sackler Symposium at NAS in Washington, DC.

—

Zhiyong Wang spoke at the West Coast Society of Developmental Biology on Mar. 25 in Asilomar, CA. He was invited to give a seminar at the Dept. of Molecular, Cell, and Developmental Biology, UCLA, on May 11, and a talk at the International Conference on the Frontiers of Plant Molecular Biology on May 22-24 in Changsha, China.

—

In Mar. postdoc **Jun-Xian He** left the Wang lab for a senior molecular biologist position at Monsanto, and visiting student **Hai-Ping Zhang** arrived at the Wang lab from the Chinese Academy of Agricultural Sciences, Beijing.

—

Seth Debolt joined Chris Somerville's lab in Mar. as a postdoctoral research associate. He came from U. Adelaide, Australia, where he received his Ph.D. in a joint program with UC-Davis. His thesis work on the mechanism of tartaric acid synthesis by wine grapes was featured in the *New York Times* and on NPR, among other venues.

Terrestrial Magnetism

Director **Sean Solomon** received a Distinguished Alumni Award from Caltech in May. That same month he assumed the chair of the Planetary Science Subcommittee of the NASA Advisory Council. In June he delivered two invited talks at a workshop on the planet Mercury, hosted by the International Space Science Institute in Bern.

—

Alan Boss gave an all-lab colloquium about giant planet formation at the Jet Propulsion Laboratory in Pasadena in Mar. He spoke about giant planet formation in Apr. at the Astronomy Dept. of Penn State U., and about new developments in extrasolar planetary science during the Kepler Mission Science Team Meeting, held at the NASA Ames Research Center in Moffett Field, CA. He also attended the International Summer School of Astrobiology, "Josep Comas i Solà," in Santander, Spain, in July.

—

Rick Carlson presented talks at the Geological Society of Washington in May. As part of the Oregon High Lava Plains Project, Carlson participated in the installation of two seismometers in June and attended the corresponding project workshop in Bend, OR, in July. In Aug. Carlson will give two keynote lectures at the 16th Annual V.M. Goldschmidt Conference in Melbourne, Australia.

—

Larry Nittler gave colloquia at the Carnegie Observatories and at UCLA in Apr. Along with postdoctoral fellow **Henner Busemann**, he participated in a Stardust mission workshop in San Francisco in May. Nittler also talked at the 208th AAS Meeting, held in Calgary in June.

—

Sara Seager attended the International Space Science Institute Life Detection Strategies Workshop in Bern in Apr. She gave a plenary talk at an International Society for Optical Engineering meeting in Orlando in May, and presented a talk at the National Academy of Sciences German-American Frontiers Meeting in June in Potsdam, Germany.

—

In Apr. and May, **Paul Silver** gave talks at Johns Hopkins U. and Central Washington U. In June Silver and geochemist **Steve Shirey** gave talks at a Penrose Conference on "When Did Plate Tectonics Begin On Earth?" Shirey delivered a keynote address on the isotopic evidence from the Archean era.

—

In May **Alycia Weinberger** facilitated workshops at the Sally Ride Science Festival for Girls held at George Mason U., at which she aided fifth to eighth graders in making spectroscopes. In Apr. Weinberger gave the Carnegie/Huntington public lecture in Pasadena and delivered an astronomy colloquium at Caltech. Weinberger served as a panel chair of the Spitzer Space Telescope time allocation committee in Apr. She also served on the NASA Keck Telescope time allocation committee and was appointed to the ALMA North American Science Advisory Committee.

—

❺ Merle A. Tuve Senior Fellow **James Elliot** of MIT spent four weeks at DTM in Mar. and Apr. He delivered a Tuve Lecture, "Exploring the Outer Solar System with Stellar Occultations."

—

Postdoctoral fellow **Alceste Bonanos** gave an invited talk at the Space Telescope Science Institute in Mar. She will give a talk at the International Astronomical Meeting Symposium on Binary Stars in Prague in Aug. DTM's **Larry Nittler** will also be attending.

—

Postdoctoral fellow **Hannah Jang-Condell** gave talks at the NASA Goddard Space Flight Center in Mar., at MIT's Department of Earth, Atmospheric, and Planetary Sciences in Apr., and at the Naval Research Laboratory's Radio, IR, and Optical Sensors branch in June.

—

Postdoctoral fellow **Mercedes López-Morales** gave an invited talk in June at the Duke Talent Identification Program for high school students, held at the Pisgah Astronomical Research Institute in NC.

—

In May postdoctoral fellow **Scott Sheppard** gave talks at U. Maryland and at the Space Telescope Science Institute. He attended a Kuiper Belt Conference in Italy in July.

—

Postdoctoral fellow **Taka'aki Taira** spoke at the Seismological Society of America's 2006 Annual Meeting, held in San Francisco in Apr.

—

Several DTM staff members and postdoctoral fellows gave talks at the 2006 AGU Joint Assembly in Baltimore, May 23-26, including **Rick Carlson**, **Larry Nittler**, **Paul Silver**, and postdoctoral fellows **Catherine Hier-Majumder** and **Taka'aki Taira**.

—

In July, postdoctoral fellows **Catherine Cooper** and **Isamu Matsuyama** attended MYRES II: Dynamics of the Lithosphere, held in Verbania, Italy.

—

Carnegie Fellow and cosmochemist **Ann Nguyen** joined DTM in Jan. Seismologist **Steven Golden** joined the dept. as the new field seismologist in Mar.

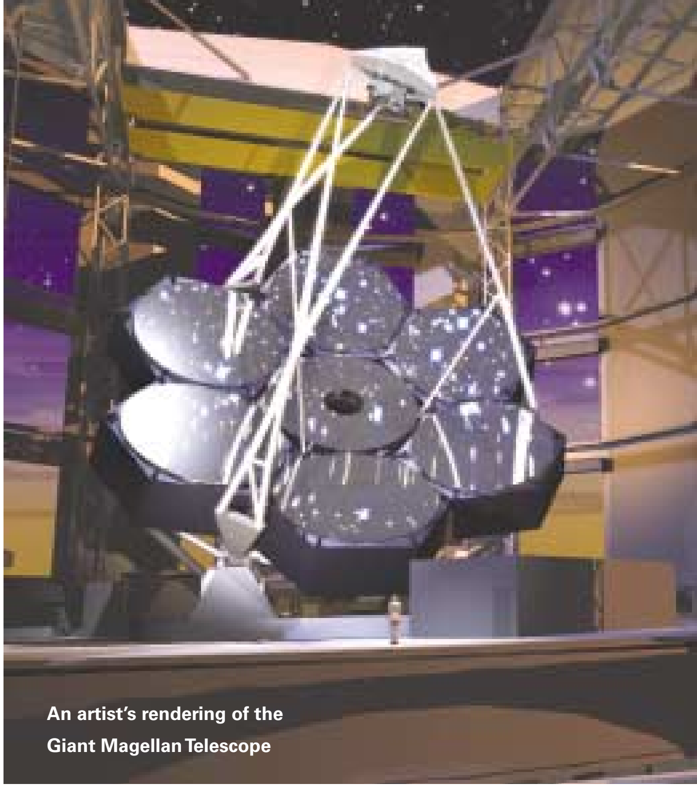
GL/DTM

Shaun Hardy presented a talk, "Shaking the Dust from 100 Years of Geophysics in the Carnegie Institution's Archives," at the Potomac Geophysical Society in Mar. He has been reappointed by the American Geological Institute to another three-year term on the GeoRef Advisory Committee, which develops ideas for collecting and providing bibliographic information to the geoscience community.

The Giant Magellan Telescope Group Grows

The Giant Magellan Telescope (GMT), the first extremely large new-generation telescope to begin production, has gained a new partner—the Australian National University (ANU) http://www.anu.edu.au/. The announcement was made on April 18 by the GMT Consortium. "The addition of the Australian National University to the GMT Consortium is the most recent indication of the momentum that the project is generating," commented Wendy Freedman, chair of the GMT board and the Crawford H. Greenewalt director of the Carnegie Observatories. "We all share a common goal of probing the most important questions in astronomy facing us over the next generation—the mysteries of dark energy, dark matter, and black holes; the birth of stars and planetary systems in our Milky Way; the genesis of galaxies; and much more."

The Giant Magellan Telescope is slated for completion in 2016 at a site in northern Chile. It will be composed of seven 8.4-meter primary mirrors arranged in a hexagonal pattern. One spare off-axis mirror will also be made. The telescope's primary mirror will have a diameter of 80 feet (24.5 meters) with more than 4.5 times the collecting area of any current optical telescope and 10 times the resolution of the Hubble Space Telescope. Detailed information about the design of the giant telescope and the science it will perform is located at http://www.gmto.org/.



(Image courtesy Todd Mason and The Carnegie Observatories.)

An artist's rendering of the Giant Magellan Telescope

Carnegie Initiates Online Giving

Starting July 1, 2006, you will be able to make a gift to the Carnegie Institution online. Visit our home page, www.carnegieinstitution.org, to find out how.

CAPITAL SCIENCE EVENINGS

are held on Thursdays at 6:45 p.m. at the Carnegie Institution administration building, 1530 P St., NW, Washington, D.C. They are free and open to the public. For more information call 202-328-6988, send an e-mail to ecarpenter@ciw.edu, or visit our Web site at www.CarnegieInstitution.org.

*Book Tour

Thursday, September 28, 2006	S. James Gates, Jr.	University of Maryland, Department of Physics/ Center for Particle and String Theory	*String Theory/Supersymmetry*
***Wednesday, October 11, 2006**	Sean Carroll	University of Wisconsin, Laboratory of Genetics/HHMI	Book tour: *The Making of the Fittest*
Thursday, November 2, 2006	Jeremy Sabloff	University of Pennsylvania, Department of Anthropology	*Mayan Archaeology*
Thursday, January 25, 2007	Steven Squyres	Cornell University, Department of Astronomy	*Mars and the Spirit and Opportunity Rovers*
Thursday, March 1, 2007	Naomi Oreskes	University of California, San Diego, Department of History	*Scientific Consensus: How We Know We're Not Wrong*
Thursday, April 5, 2007	David Page	Whitehead Institute	*The Y Chromosome*
Thursday, May 10, 2007	Luis Ho	The Carnegie Observatories	*Black Holes*

Carnegie Institution of Washington
1530 P Street, NW
Washington, D.C. 20005-1910

Nonprofit Org.
U.S. POSTAGE
PAID
Washington, DC
PERMIT NO.1657