Carnegie*Science*

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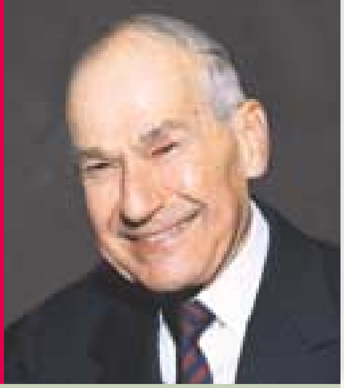

(Image courtesy Richard Holden Photography.)

Great enthusiasm was apparent

as astronomers, administrators, and supporters from eight institutions gathered for the historic casting of the first 8.4-meter mirror for the Giant Magellan Telescope (GMT) in Tucson this July (see page 5). The GMT is the first extremely large next-generation telescope to begin production. Had George Ellery Hale and Andrew Carnegie been there that day, they would have been proud to see that the institution's tradition of pushing the limits of telescope design is stronger than ever. One hundred years ago those men embarked on building the world's largest telescopes of their time—Carnegie's 60- and 100-inch reflectors on Mount Wilson. These telescopes dominated astronomy for years, and the discoveries they allowed completely altered our view of the cosmos.

The differences between the telescopes of a century ago and the GMT go well beyond size, mirror technology, and instrumentation. In the past, it was enough to marshal support from just a few individuals and organizations. Today, many institutions and supporters must pull together to meet the challenges of a project as enormous as the GMT. Carnegie is especially well positioned to meet these challenges with its strong legacy of contributing to large scientific efforts, catalyzing collaborations, and garnering supporters.

One major collaboration, managed by the Geophysical Lab, is the High Pressure Collaborative Access Team (HPCAT) at the large synchrotron ring at the Advanced Photon Source in Argonne, Illinois. Scientists from six partner organizations use the high-energy X-rays generated by the synchrotron to understand the behavior of matter under extreme conditions. They have discovered new materials and previously unknown fundamental properties, and their results would not be possible without a large, multi-institutional effort.

Scientists in every Carnegie department routinely work with researchers from other organizations, pooling resources, talent, and tools to build communities and pursue like interests. Plant biologists from all over the world, for instance, access what has become perhaps the most heavily used biological database. It is known as TAIR (The *Arabidopsis* Information Resource), a collaborative effort directed from the Department of Plant Biology. The TAIR staff consolidates and organizes tremendous amounts of information about the widely used model plant *Arabidopsis*. The database receives over 5 million "hits" each month and has become an indispensable source of information for the entire plant biology community.

The twin 6.5-meter Magellan telescopes at Carnegie's Las Campanas Observatory provide the most pertinent example of successful collaboration and community building. One of Carnegie's most ambitious projects, the development and construction of the Magellans would not have been possible without the contributions of multiple organizations and philanthropists. The Magellan consortium is in fact the foundation for the GMT consortium. The partners have embraced the GMT project and are pleased to welcome two newcomers—the University of Texas, Austin, and Texas A&M University—to the group. As the awareness of the promise of the GMT continues to spread, support for the project has been steadily gaining momentum.

For the institution to maintain its leadership in scientific discovery, advancement in *all* areas of Carnegie research is essential. We have long been able to balance different demands, and we expect to continue to do so. Ours is a history filled with big challenges, and they have driven our biggest achievements. The new community that has emerged for the GMT is a vibrant one. I am confident that, as others witness history being made, the GMT circle will widen, adding to its ranks more institutions and individuals who share our vision to expand the boundaries of knowledge.

—Michael E. Gellert, *Chairman*

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TRUSTEE News

Carnegie Trustees Meet in Washington

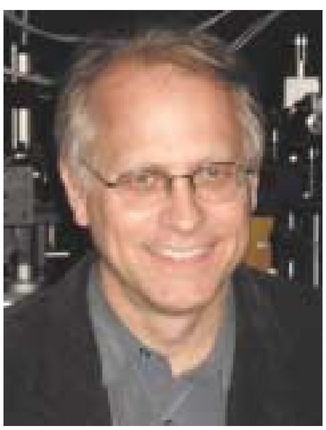
The 122nd meeting of the Carnegie board of trustees took place at the administration building in Washington, D.C., over two days, May 5 and 6. The Employee Affairs, Finance, Development, and Nominating committees met as well as the full board.

The six department directors gave reports to the trustees about significant research at their departments. David Ehrhardt, staff member at the Department of Plant Biology, concluded the meetings with a presentation about his work viewing living plant cells using confocal microscopy, *Spying on the Secret Life of Plant Cells.*

Ehrhardt's video-rich presentation demonstrated that plants are not as static as was once thought. He delved progressively deeper into the workings of plants, beginning with large structures like leaves, then moving on to collections of cells, and ending with a look at the world of the surprisingly fast-moving cell parts, the organelles. By tagging organelles with green fluorescent protein, Ehrhardt's imagery revealed how different plant parts behave as cells grow and divide. A highlight of his presentation was the results from his research into plant microtubule behavior. Microtubules, stringlike structures made of a protein called tubulin, help move chromosomes into two daughter cells when a cell divides. Microtubules differ significantly in plants and animals, and it was difficult, until the advent of Ehrhardt's pioneering live-action movies, to observe their behavior in plants.

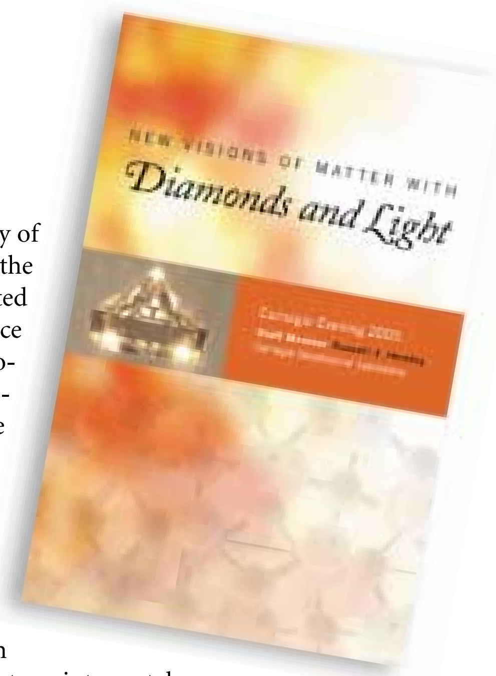
See http://deepgreen.stanford.edu/ for more information on Ehrhardt's work.

New Visions of Matter with Diamonds and Light—**Carnegie Evening 2005**



Amid the allure of diamonds, Russell Hemley of the Geophysical Laboratory (GL) took the Carnegie Evening audience on an illustrated tour through a hundred years of the science and mysteries of matter. GL emerged as a principal innovator at every step of the way, deciphering the fundamental forces at work when matter morphs under extreme pressures and temperatures, such as those found in planetary interiors.

To orient the uninitiated, Hemley showed the pressure ranges found in the universe (see page 4), from the conditions of intergalactic space to the center of a neutron star. He then described what happens to atoms and their orbiting electrons when matter is squeezed intensely, as in the crushing depths of planets. Under such extreme conditions, materials change unexpectedly and novel structures abound: Gases turn into metals; exotic forms of water ice become denser than the liquid; superconductors materialize from myriad elements; and solids take on bizarre electronic and magnetic properties.



Carnegie's Russell Hemley spoke on the state of high-pressure physics at the 2005 Carnegie Evening lecture.

Hemley highlighted the work of some of the legendary researchers at the lab, describing the tools they developed to induce extreme conditions and to image what goes on as materials change. Among the earliest innovators was Erskine Williamson, who, some 90 years ago, predicted the pressure at Earth's center at 3.2 million times the pressure at sea level, a figure remarkably close to its actual 3.6 million atmospheres (1 atmosphere is the pressure at sea level). Ho-kwang (Dave) Mao's and Peter Bell's milestone achievement in the late 1970s to reach 1 million atmospheres with the diamond anvil cell was also noted. Finally, Hemley paid tribute to the late Hatten Yoder, former director of GL, and to staff member Joe Boyd and the ingenious methods they devised over the decades for inducing high pressures.

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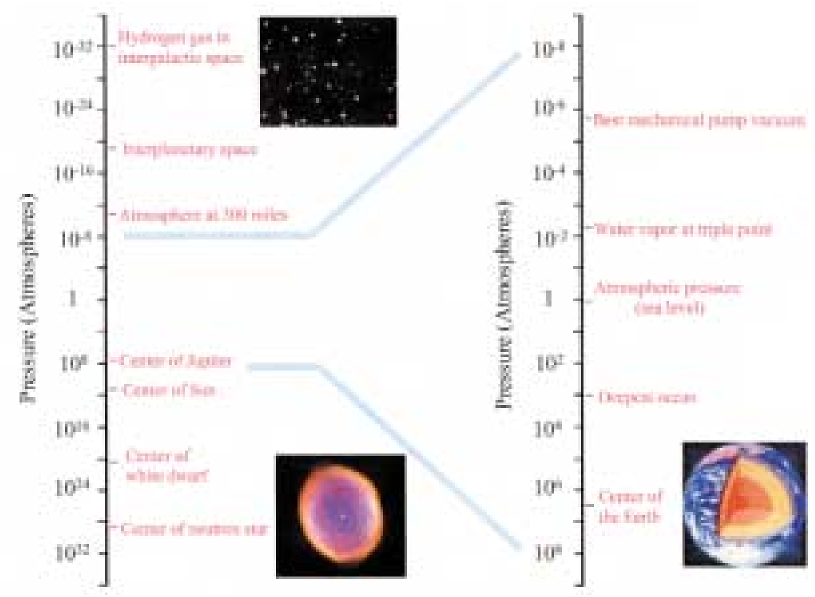
Range of Pressure in the Universe



The range of pressures in the universe varies tremendously, from the tenuous gases of intergalactic space to the crushing depths of planetary interiors.

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Outlining the contemporary state of the science, Hemley described the arsenal of the latest "imaging" tools and described some new disciplines impacted by high-pressure studies. Today the GL team uses light over a broad wavelength spectrum to watch what happens as pressure is varied. The largest tool is at the Advanced Photon Source at Argonne, Illinois. There, at the facilities of the High Pressure Collaborative Access Team, high-energy X-rays have wavelengths so tiny they are comparable to the distances between atoms and can thus detect new atomic arrangements. Lasers, synchrotron infrared sources, neutron scattering, and numerous other techniques are also used to explore the "brave new world" that this science of the extreme has entered.

High-pressure research is not just useful for understanding planets, as Hemley made clear. Researchers are also eager to apply these methods to understanding stellar interiors and how pressure and temperature regimes can be used to lock hydrogen into tiny cages called clathrates to store environmentally clean hydrogen power. Others are investigating the nature of superconductors, hoping for the day when these highly efficient energy transmitters are commonplace. There is also the dawn of "extreme biology," as Hemley dubbed it. Surprisingly, Carnegie scientists discovered that microbes subjected to extreme high-pressure conditions can survive, raising the possibility that life could exist in the viselike pressures inside planets or moons or other similarly hostile environments.

Hemley ended his talk by describing the current challenges in the field, in particular focusing on the workhorse of high-pressure research—the diamond anvil cell. In experiments using this equipment, matter is placed between two small diamond tips and compressed while probes monitor the changes. The GL team has been advancing this device in tandem with developments in its research. Currently the team is growing large, exceptionally tough diamonds faster than anyone else in the world, via a process called chemical vapor deposition. The goal is to make diamonds bigger than 100 carats for the next-generation instruments that will propel our understanding of how matter behaves under extreme conditions. •

FRETting over Brain Cells at Plant Biology

Brain and plant cells would not appear to have a lot in common; but scientists at Carnegie's Department of Plant Biology have found that a technique used to watch cells process chemicals can be used in both. The neurotransmitter glutamate is the major brain chemical that increases nerve-cell activity in mammalian brains. It is involved in everything from learning and memory to mood and perception. Too much glutamate may contribute to conditions such as Alzheimer's and Parkinson's disease. Until now it has been impossible to accurately measure the levels of any important chemicals in living brain cells in real time and at the level of a single cell. Scientists at Plant Biology and Stanford University are the first to overcome this obstacle by successfully applying genetic nanotechnology using molecular sensors to view changes in brain chemical levels. The technology is fluorescence resonance energy transfer, or FRET, which has been used in Wolf Frommer's Plant Biology lab for some time. "The fluorescent imaging technique allows us to see living cells do their jobs live and in color," explained Sakiko Okumoto, lead author of the study at Carnegie. The research was published in the May 30-June 3 online early edition of the *Proceedings of the National Academy of Sciences.*

> *"It's fascinating to see a tool that we are using in plant biology open new areas in neuroscience."*

The diverse group of scientists introduced the nanosensors into nerve cells to measure the release of glutamate. "Understanding when and how glutamate is produced, secreted, reabsorbed, and metabolized in individual brain cells, in real time, will help researchers better understand disease processes and construct new drugs," commented Okumoto. "FRET is like two musical

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Cast Party

(Image courtesy David Harvey Photography.)

Observatories director Wendy Freedman greets guests affiliated with the Giant Magellan Telescope partnership at the kickoff luncheon for the mirror-casting event.

"The only way…is for institutions and people to pull together."

(Image courtesy David Harvey Photography.)

(Image courtesy David Harvey Photography.)

(Image courtesy David Harvey Photography.)

Top, groups of guests were taken on a tour of the Steward Observatory Mirror Laboratory as the Giant Magellan Telescope mirror was cast.

Center, guests gather after the tours of the mirror lab for a rooftop reception.

Bottom, Carnegie president Richard Meserve stands next to a model of the GMT as he speaks at the reception held after the tour.

In the middle of a scorching heat wave, over 130 astronomers and supporters from eight institutions met on July 23 in Tucson, Arizona, to witness pure glass reach the critical 2150°F melting point for the casting of the first mirror for the Giant Magellan Telescope (GMT). The delicate operation was a resounding success. The GMT is the first extremely large telescope in the world to begin production, and the mirror is the first 8.4-meter so-called off-axis mirror to be made for the 80-foot (24.5 meters) next-generation ground-based reflector. The technology for its unique lightweight "honeycomb" design, pioneered by the University of Arizona's Steward Observatory Mirror Laboratory, was used earlier in the unsurpassed 6.5-meter Magellan telescope mirrors at Carnegie's Las Campanas Observatory in Chile and in two 8.4-meter mirrors for the Large Binocular Telescope on Mount Graham in Arizona.

A luncheon kicked off the historic event on a rooftop offering a view as expansive as the telescope's potential. Wendy Freedman, director of the Carnegie Observatories and chair of the GMT board, welcomed the new community of GMT partners and guests to the history-making day. She introduced George Davis, provost of the University of Arizona, who emphasized the importance of the project to his institution. John Huchra, Harvard vice provost for research policy, then spoke, recalling how his university became involved in the original Magellan project and stressing the importance of the strong relationships built for that effort. Finally, Roger Angel, the mirror lab's science director and the genius behind the mirror design, took to the podium. Angel gave a brief mirror-making tutorial and outlined what the crowd would see that day, including the opportunity to watch via camera as the glass made the transition from the viscous to the liquid state and then flowed to envelop the 1,681 hexagonal cores that make up the mirror mold. He highlighted the challenge of producing the first off-axis, or aspheric, GMT mirror and how "the wicked curvature" would be achieved, which will be done primarily through grinding and polishing the glass to within about 15 billionths of a meter.

After lunch, shuttle buses ferried the enthusiastic crowd to the mirror lab, tucked away in an unlikely spot under the university's football stadium. The tours began with a large-

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screen projection showing the progress of the melting glass. Next stop was the furnace room, where the two-story, 40-foot, flying-saucer-shaped oven was spinning at a speed of about five rotations per minute. Other tour stops included the test tower, which will be adapted for the giant telescope to evaluate the optical conditions as the aspherically curved mirrors are polished. Although creating aspheric mirrors is the major technical challenge currently facing the project, the lab is already developing the technology with a 1.7-meter mirror that is an approximate scale for the GMT. It will be used for the New Solar Telescope at Big Bear Solar Observatory.

"We are getting back to our roots," stated Carnegie president Richard Meserve at the predinner reception after the tours. Meserve reviewed Carnegie's rich history in pushing the limits of telescope design, which began a century ago with George Ellery Hale and the 60- and 100-inch telescopes on Mount Wilson. It continues today with the Magellan telescopes at Las Campanas. "We don't know very much about the 95% of the universe that is made up of dark matter and dark energy," Meserve said, speaking enthusiastically of "the extraordinary science that will result from the GMT."

"We are getting back to our roots."

Other members of the GMT community also spoke. "There's no doubt about the real thing," stated David Evans, undersecretary for science at the Smithsonian, who talked about how the new telescope would be an "inspiration" to boost the calling of science. "We are able to tackle really big, important problems," commented Sheldon Ekland-Olson, executive vice president and provost of the University of Texas at Austin, emphasizing that "the only way to tackle the problems is for institutions and people to pull together." Joseph Newton, dean of the College of Science at Texas A&M, proclaimed that "a miracle is happening at Texas A&M" and thanked the generosity of supporter George Mitchell for his role in helping the university with the project. Doug Richstone, chair of the Department of Astronomy at the University of Michigan, echoed the enthusiasm for the GMT. "It's interesting to look to the future," he reflected.

Both the serious and the comedic were on tap for the after-dinner talks. "I was struck by how small the telescope is," commented Observatories staff astronomer Pat McCarthy, comparing the size of the GMT with the vastness of the universe it will explore. McCarthy explained how the GMT's enormous light-collecting power will thrust our knowledge of black

(Images courtesy Lori Stiles, UA News Service.)

It took seven weeks for the team to install the ceramic cores to make the mold for the Giant Magellan Telescope's first mirror. Randy Lutz, who leads the casting team, is ready to install the last core in late May.

After a thorough inspection, the mirror-lab casting team loads 40,000 pounds of highly pure Japanese Ohara Glassworks borosilicate glass into the Giant Magellan Telescope mirror mold.

(Image courtesy David Harvey Photography.)

To spin cast the mirror, the furnace is heated to a maximum temperature of 2150°F. At that point the glass melts to flow between the cores, creating the honeycomb shape. For the Giant Magellan Telescope mirror, the furnace rotates just under five times per minute.

hole formation, the origins of stars and galaxies, the nature of planets around other stars, and the events during the first billion years after the Big Bang to an unprecedented level. He then described how new advanced adaptive optics technology will be used to compensate for "dancing smush," the blurring effects from the atmosphere that are the bane of optical astronomy.

The evening concluded with stand-up science comedian Bob Kirshner, who by day is the Clowes Professor of Science at Harvard's Department of Astronomy. "It's not your father's universe," he began, going on to entertain the audience with one-liners about the history of astronomy, the GMT consortium, and the future of the field when the new telescope comes online. For Kirshner, the GMT will provide the "joy of finding out how the world works." The telescope is slated for completion in 2016 in Chile.

Why Bigger Is Better

A large telescope can collect more light and thereby enables the detection of fainter, farther-away objects. That capability is important to cosmology because the farther one looks in distance, the farther one sees back in time. The Giant Magellan Telescope will be able to collect light from an era closer to the Big Bang than any other telescope to date. It will have a collecting area 4.5 times larger than that of the best ground-based optical telescope today and 10 times the resolution of the Hubble Space Telescope.

The GMT primary mirror will consist of seven 8.4-meter mirrors—one parabolic mirror in the middle surrounded by six other aspheric mirrors that, when all aligned, will form a perfect parabolic reflector with an effective diameter of 24.5 meters, or 80 feet. An extra off-axis mirror will also be made.

Making the Mirror

Over seven weeks beginning in April, the casting team installed about 50 hexagonal cores each day in the mirror mold. Beginning in late June, 20 tons of special borosilicate glass from Ohara Glassworks in Japan were inspected for impurities. And on July 12, the team loaded the glass into the mold. To reach the peak temperature of 2150°F, the lab fired up the furnace on July 18. Finally, on July 23, the thick, liquid glass flowed around the cores to make the lightweight honeycomb structure.

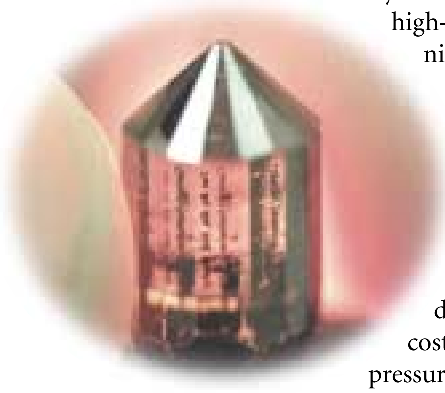
During spin casting, the furnace uses as much electricity as would be required to power about 1,000 Tucson households. The rate at which the 100-ton oven spins determines the depth of the mirror's curve. Unlike other mirrors made at the lab, this aspheric mirror requires a slower speed of 4.8 times per minute to make a longer focal length and shallower depth. The mirror will be slowly cooled for approximately three months, after which time the ceramic cores will be washed out of the mirror's glass. The resulting mirror will be ground and polished, with the final polishing to be completed in November 2008. Finally, the mirror will be coated in reflective aluminum. Upon completion it will weigh only about a fifth as much as a solid glass mirror of the same size.

"There's no doubt about the real thing."

The GMT consortium currently includes the Carnegie Observatories, Harvard University, the Smithsonian Astrophysical Observatory, the University of Arizona, the University of Michigan, the Massachusetts Institute of Technology, the University of Texas at Austin, and Texas A&M University.

10 Carats and Growing: Diamond Bonanza at GL

The diamond-making team at Carnegie's Geophysical Laboratory has learned to produce 10-carat, half-inch-thick, single-crystal diamonds at the astounding rate of 100 micrometers per hour using a special chemical vapor deposition (CVD) process. This new 10-carat size is about five times the size of commercially available diamonds produced by the standard high-pressure/high-temperature (HPHT) method and other CVD techniques. The team has additionally made colorless single-crystal diamonds that are transparent from the ultraviolet to infrared wavelengths. New shapes have also been fabricated with the blocks of the CVD single crystals.



The standard growth rate is 100 micrometers per hour for the Carnegie process, but growth rates in excess of 300 micrometers per hour have been reached, and 1 millimeter per hour may be possible. With the colorless diamond produced at an ever higher growth rate and at low cost, large blocks of diamond should be available for high-pressure research and a variety of other applications.

The Carnegie high-growth-rate CVD process allows for a variety of single-crystal diamond types.

The 1/2 inch (12 mm) 5-carat diamond (far left) came from a 10-carat single crystal produced by the team's high-growth-rate CVD process. The diamond was cut by a laser from a diamond block, inscribed, and only partly polished.

Rock Hounds Sleuth Rise of Earth's ATMOSPHERE

"CSI-like" techniques are uncovering the steps that led to the rise of Earth's atmosphere. In his landmark paper on the subject appearing in the May/June *American Mineralogist,* president of the Mineralogical Society of America and Geophysical Laboratory staff scientist Douglas Rumble III describes the suite of techniques developed and the studies undertaken over the last five years that have led to a growing consensus by the scientific community on what happened to produce the protective ozone layer and atmosphere on our planet.

"Rocks, fossils, and other natural relics hold clues to ancient environments in the form of different ratios of isotopes—atomic variants of elements with the same number of protons but different numbers of neutrons," explained Rumble. "Seawater, rainwater, oxygen, and ozone, for instance, all have different ratios, or fingerprints, of the oxygen isotopes ^{16}O, ^{17}O, and ^{18}O. Weathering, groundwater, and direct deposition of atmospheric aerosols change the ratios of the isotopes in a rock, revealing a lot about the past climate." Rumble's paper describes how geochemists, mineralogists, and petrologists are studying anomalies of isotopes of oxygen and sulfur to piece together what happened to our atmosphere from about 3.9 billion years ago, when the crust of our planet was just forming and there was no oxygen in the atmosphere, to a primitive oxygenated world 2.3 billion years ago, and from that time to the present.

The detective work involves a pantheon of scientists who have analyzed surface minerals from all over the globe, used rockets and balloons to sample the stratosphere, collected and studied ice cores from Antarctica, conducted lab experiments, and run mathematical models. The synthesis from the different fields points to ultraviolet (UV) light from the Sun as an important driving force in atmospheric evolution. Solar UV photons drive the production of ozone in the atmosphere and yield ozone that is enriched in ^{17}O and ^{18}O, thereby leaving a telltale isotopic signature. The ozone layer began to form as the atmosphere gained oxygen and has since shielded our planet from harmful solar rays, making life possible on Earth's surface.

"The discovery of isotope anomalies where none were previously suspected adds a new tool to research on the relationships between shifts in atmospheric chemistry and climate change. Detailed studies of polar-ice cores and exposed deposits in Antarctic dry valleys may improve our understanding of the history of the ozone hole," Rumble said.

Funding for this work came from the following institutions: NASA, the NASA Astrobiology Institute, the National Science Foundation, the Jet Propulsion Laboratory, and the Carnegie Institution of Washington.

Did Humans Cause **Ecosystem Collapse** in Ancient Australia?

(Image courtesy Marilyn Fogel.)

Marilyn Fogel dissects a modern emu egg for her study on the ancient Australian environment.

Massive extinctions of animals and the arrival of the first humans in ancient Australia may be linked, according to a group of scientists that includes Marilyn Fogel of Carnegie's Geophysical Laboratory. The researchers traced evidence of diet and the environment contained in ancient eggshells and wombat teeth over the last 140,000 years to reconstruct what happened. The remains showed evidence of a rapid change of diet at the time of the extinctions. The researchers believe that large-scale fires set by the first humans may have altered the ecosystem of shrubs, trees, and grasses to the fire-adapted desert scrub of today. The work was published in the July 8 issue of *Science*.

By studying their eggshells, the scientists plotted diet changes over 140,000 years in two species of large, flightless birds—the now-extinct *Genyornis* and the surviving emu *(Dromaius)*—in three Australian locations. They then corroborated their findings by analyzing ancient wombat teeth. "What your mother told you is true: You are what you eat," stated coauthor Fogel. Eggshells and teeth both contained evidence of these animals' diets in different forms of carbon.

All three animals were plant eaters. Since different types of plants metabolize different forms of carbon in distinctive ways from the CO_2 they take up during photosynthesis, the varieties of carbon preserved in the eggshells and teeth told the researchers what types of plants the animals ate. The analysis revealed a sudden shift in plant type coincident with the arrival of humans, and this shift in diet shed light on the extinctions. The animals, such as *Genyornis*, that relied mostly on the more palatable plant forms died out, while the animals, such as the emu, that adapted to the less nutritious plants survived.

There are three isotopes, or varieties, of carbon found in nature—^{12}C, ^{13}C, and ^{14}C. They differ in the number of neutrons in the nucleus. By far the most abundant variety is the lightest, ^{12}C. About 1% is ^{13}C, a heavier sibling with an additional neutron. There is even less ^{14}C, the unstable, radioactive heavyweight of the group.

Fogel explained that ^{13}C is the key. "There are two main ways plants metabolize ^{13}C. About 85% of plants belong to what is known as the C3 photosynthesis group. This group incorporates less ^{13}C than plants belonging to the second most common class, C4. Thus, the differences in ^{13}C that we detected in the eggshells and teeth pointed to the type of plants that were consumed. Although both types of plants were present before the extinctions, we saw a quick shift in dominance from C4 drought-resistant trees, shrubs, and grasses to C3 desert plants."

Why did the scientists point to humans as the instigators of the ecological changes? First, they ruled out the other usual suspect—global climate change—by looking at their data in 15,000-year intervals back to 140,000 years ago. The period included dramatic climate changes, but no changes in diet until an abrupt transition was noted that corresponded to the arrival of humans. "Humans are the major suspect," said Fogel. "However, we don't think that overhunting or new diseases are to blame for the extinctions, because our research sees the ecological transition at the base of the food chain. Bands of people set large-scale fires for a variety of reasons, including hunting, clearing, and signaling other bands. Based on the evidence, human-induced change in the vegetation is the best fit to explain what happened at that critical juncture."

(Image courtesy Marilyn Fogel.)

Ancient emu eggshell fragments (above) were essential in piecing together what happened to change the ancient environment.

The study was funded by the National Science Foundation. Other coauthors are Gifford Miller of the University of Colorado; John Magee and Mike Gagan of the Australian National University; Simon Clarke, a student at Carnegie's Geophysical Laboratory; and Beverly Johnson at Bates College.

(Image courtesy Alice Chen.)

Cell Talk and Tissue Development

Untangling the Conversation

From the very first spark of conception, cells in our bodies talk to each other to ensure that tissue development stays on course and diseases such as cancer are kept at bay. Scientists at the Department of Embryology recently found an entirely new way this conversation works.

Cell-to-cell communication takes place via complex molecular relays among biochemicals. A molecule sent from one cell interacts with a receptor at the surface of a second cell. That surface molecule in turn relays information to a molecule inside the target cell, which can tag yet another molecule and so on until the information eventually gets to the nucleus, where a gene is turned on that will tell the cell what tissue to become—bone, muscle, brain, etc. Remarkably, there are only seven or eight of these "signaling pathways," which control all developmental cell transformations in all bilateral animals. Although few in number, these pathways vary tremendously in their complexity and, until recently, were thought to be distinctive. That notion has been changing.

(Image courtesy Alice Chen.)

Alice Chen was a predoctoral associate in Carnegie's Department of Embryology when she and colleagues discovered the new Wnt/CREB molecular signaling pathway. She is now at Harvard as a postdoctoral associate studying stem cell biology and diabetes.

A Surprising New Way to Signal

Pathbreaking work, literally, by Alice Chen, formerly a predoctoral associate at the Department of Embryology, David Ginty, a Howard Hughes investigator at Johns Hopkins, and Embryology staff member Chen-Ming Fan has found a new signaling pathway that governs muscle development in mice. It appears to be a merger of parts of two pathways that were previously believed to be completely different. The discovery has the potential to boost the understanding of how stem cells renew and how cancer forms. Their work was published in the January 20, 2005, issue of *Nature.*

To follow the molecular trail, the researchers traced which molecules do what in the development of skeletal muscles along the backs of embryonic mice. They focused on a family of proteins in the so-called Wnt pathway, which is known to be important for various aspects of early embryonic development, stem cell renewal, and tumor growth. The name Wnt is a contraction of two terms identifying two genes that encode related proteins. One is the *wingless (wg)* gene in *Drosophila* and the other is the *Int-1* gene in the mouse. The Wnt protein is known as a ligand—an emissary molecule that binds to a receptor at the surface of a target cell and initiates the relays inside that target. Although the Wnt pathway was a likely suspect in this type of muscle development, it was not known what molecules were at work inside the target cell to eventually turn on the muscle-making genes *Pax3*, *MyoD*, and *Myf5*.

Tracing Who Talks to Whom

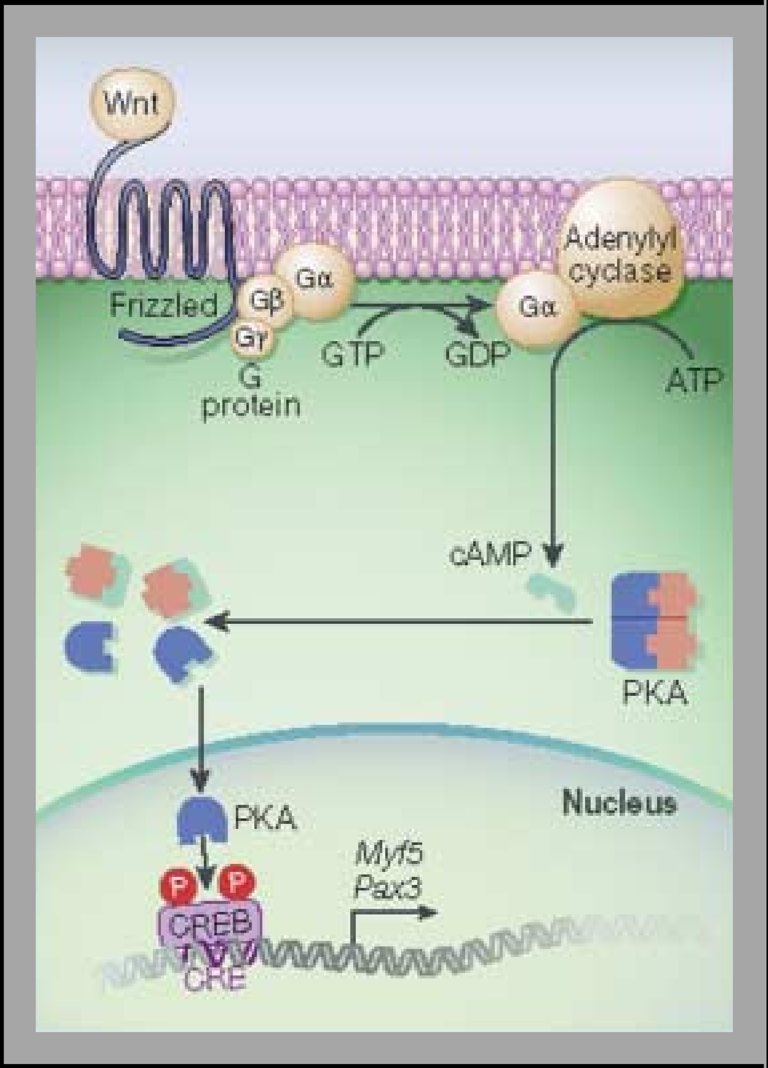
To trace the molecular relay, the scientists used a variety of tests including the application of a fluorescent antibody, which turned out to mark cells that were beginning to form precursor muscle cells. The antibody reacted to a well-known gene transcription factor—a protein in the nucleus near the end of the pathway, which begins the synthesis of RNA from the DNA template and turns genes on. The transcription factor is known as CREB (for cAMP-response-element-binding protein) and is typically classified in a different signaling pathway from one initiated by Wnt.

The researchers were surprised to find CREB near the end of the Wnt pathway. So, to make sure it was necessary for the muscle-making process and to find out what other intermediary molecules were at work, they performed a variety of additional tests. They observed what happened in mice deficient in the gene encoding CREB and developed a novel technique of infecting mouse embryos with defective forms of two molecules to see how development was affected when the proteins were not at work. One molecule was a defective form of CREB. The other was a defect in a molecule that is known to be involved in prompting CREB into action. That molecule is protein kinase A (PKA). Protein kinases are enzymes that change other proteins by adding phosphate groups in a process called phosphorylation. PKA enters the cell's nucleus and activates CREB, which then regulates gene expression; that is, it turns on the genes. The scientists found that, indeed, if CREB or PKA function is blocked, muscle differentiation does not occur—which indicates that the molecules are fundamental to the process.

Using in vitro culture of early embryonic tissue from which muscle cells are derived during development, the scientists also discovered a third molecule that stimulates muscle gene expression. It typically resides outside the nucleus, upstream in the pathway from PKA. That molecule is a catalyst called adenylyl cyclase (AC).

Until now it was never suspected that a pathway beginning with Wnt could stimulate signaling via adenylyl cyclase, PKA, and CREB (and other molecules yet to be identified). The discovery surprised Chen and colleagues and the biological community at large. Their work has received enormous attention and has called into question just how many pathways there really are controlling tissue development and how distinctive they may or may not be.

Alice Chen has gone on to Harvard for her postdoctoral work in stem cell biology and diabetes research. She has received wide recognition for her discoveries on the Wnt pathway, including a 2005 Harold M. Weintraub Graduate Student Award. Meanwhile, the Fan lab at Embryology continues to define the roles of new and old Wnt pathways in muscle differentiation. They are interested in understanding how pathways, beginning with Wnt, talk to each other within the cell to instruct muscle development. Since Wnt signaling is also known for its role in stem cell renewal, the lab is particularly excited about testing whether this newly discovered Wnt/CREB pathway also stimulates muscle stem cells to make muscle in adult mice.



(Image courtesy Nature Publishing Group.)

A chain reaction of molecules results in turning genes on inside the nucleus of a cell. Alice Chen and colleagues 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, a transcription factor that begins the synthesis of RNA from the DNA template to activate a gene, was part of the chain reaction initiated by Wnt.

(Image courtesy NOAA.)

Marine organisms like these could be adversely affected by an increase in ocean acidity.

Ecological Alarm: Oceans Turning to Acid from Rise in CO_2

On July 1, 2005, his first day at work at the Department of Global Ecology, Ken Caldeira was featured in the *New York Times* and other news outlets in connection with a report he coauthored, issued by the Royal Society in the U.K., that sounds the alarm about the world's oceans. "If CO_2 from human activities continues to rise, the oceans will become so acidic by 2100 it could threaten marine life in ways we can't anticipate," he stated.

Many scientists view the world's oceans as an important sink for capturing the human-induced greenhouse gas CO_2 and slowing global warming. Marine plants soak up CO_2 as they breathe it in and convert it to food during photosynthesis. Organisms also use it to make their skeletons and shells, which eventually form sediments. With the explosion of fossil-fuel burning over the past 200 years, it has been estimated that more than a third of the human-originated greenhouse gas has been absorbed by the oceans. While marine organisms need CO_2 to survive, work by Caldeira and colleagues shows that too much CO_2 in the ocean could lead to ecological disruption and extinctions in the marine environment.

When CO_2 gas dissolves into the ocean it produces carbonic acid, which is corrosive to shells of marine organisms and can interfere with the oxygen supply. If current trends continue, the scientists believe the acidic water could interrupt the process of shell and coral formation and adversely affect other organisms dependent upon corals and shellfish. The acidity could also negatively impact other calcifying organisms, such as phytoplankton and zooplankton, some of the most important players at the base of the planet's food chain.

"We can predict the magnitude of the acidification based on the evidence that has been collected from the ocean's surface, the geological and historical record, ocean circulation models, and what's known about ocean chemistry," continued Caldeira. "What we can't predict is just what acidic oceans mean to ocean ecology and to Earth's climate. International and governmental bodies must focus on this area before it's too late."

The pH (potential of hydrogen) scale is from 1 to 14, with 7 being neutral. Anything that lowers pH makes the solution more acidic. The scientists calculated that over the past 200 years the pH of the surface seawater has declined by 0.1 units, which is a 30% increase in hydrogen ions. If emissions of CO_2 continue to rise as predicted by the Intergovernmental Panel on Climate Change's IS92a scenario, there will be another drop in pH by 0.5 units by 2100, a level that has not existed in the oceans for many millions of years. In addition, the changes in the oceans' chemistry will reduce the capacity to absorb CO_2 from the atmosphere, which in turn will accelerate the rate of global warming.

"This report should sound the alarm bells around the world," warned Chris Field, director of Global Ecology. "It provides compelling evidence for the need for a thorough understanding of the implications of ocean acidification. It also strengthens the case for rapid progress on reducing CO_2 emissions." •

Ken Caldeira Joins Global Ecology Staff

Ken Caldeira has a wide-angle view on global ecosystems. He investigates the global carbon cycle, marine biogeochemistry, the long-term evolution and numeric modeling of climate and geochemical cycles, chemical oceanography, ocean carbon sequestration, and energy technology. He comes to the Department of Global Ecology from the Energy and Environment Directorate at the Lawrence Livermore National Laboratory, where he has been since the early 1990s. His work at Carnegie is supported by the Gordon and Betty Moore Foundation.

Caldeira serves on many national and international panels and committees. He is the coordinating lead author of the upcoming Intergovernmental Panel on Climate Change (IPCC) Special Report on CO_2 Capture and Storage. He was also recently appointed to an ocean acidification task force of the International Geosphere-Biosphere Programme and is a lead author on energy technologies for the State of the Carbon Cycle Report being developed by the U.S. government, in addition to his many other affiliations.

Caldeira received his B.A. from Rutgers College and went on to New York University, where he received both his master's (1988) and his Ph.D. (1991) in atmospheric sciences.

Ken Caldeira joined the scientific staff of the Department of Global Ecology on July 1.

(Image courtesy NASA/JPL-Caltech/R. Hurt, SSC.)

Homing In on Other Earths

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.

The ultimate dream of planet hunters is to identify other worlds around nearby stars that have the potential to harbor life. To reach this brass ring, astronomers are refining techniques to detect chemicals that may comprise distant life-promoting atmospheres, and to locate planets with masses similar to Earth's at distances from their stars similar to the Earth-Sun distance. This race to find life elsewhere in the galaxy has been heating up in recent months, and researchers at the Department of Terrestrial Magnetism (DTM) are leaders of the pack.

First Light Detected from an Extrasolar Planet

Most of the 150 known extrasolar planets have been discovered and studied through techniques such as finding the telltale wobble of a star tugged by an orbiting planet, or the "blink" of a star as a planet passes in front of it. Now scientists, including DTM's Sara Seager, have observed an extrasolar planet through the light it emits in the infrared. "I feel we've been blind and have just been given sight," commented Seager. "Detecting light from these other worlds is very exciting. It's the beginning of our ability to study their temperature and composition." The study, published in the March 23 online edition of *Nature*, used measurements from NASA's Spitzer Space Telescope, an infrared observatory launched in August 2003.

The planet, HD 209458b, is a so-called hot Jupiter—a massive gaseous world that orbits very closely to its parent star in only 3.5 days. It has not yet been possible to 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 than they do at visible wavelengths, making them detectable. HD 209458b was discovered indirectly in 1999 and was later found to transit its star—the star dims as the planet moves in front of it during the course of the planet's orbit. Using the Spitzer, the astronomers first measured the combined light of the planet and the star just before the planet went out of sight. Then, 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 emitted. The results of the measurements agreed with models created to determine how much infrared radiation hot Jupiters are likely to emit. HD 209458b was found to be a scorching 1574°F (1130 K), confirming that hot Jupiters are in fact intensely baked by their nearby stars.

Most Earth-like Planet Yet

On June 13, 2005, a team of astronomers, including DTM's Paul Butler, announced the discovery of the smallest extrasolar planet

(continued on page 14)

(Image courtesy Lynette Cook.)

This is an artist's rendering of 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.

(continued from page 13)

yet detected. The scientists believe that it 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. The research was conducted at the Keck Observatory in Hawaii and was widely reported on by the media.

"This is the smallest extrasolar planet yet detected and the first of a new class of rocky terrestrial planets,"said Butler. "It's like Earth's bigger cousin." The ability to detect the tiny wobble as the planet tugs its star gives astronomers confidence that they will be able to detect even smaller rocky planets at orbital distances more conducive to harboring life.

All of the other extrasolar planets discovered to date around Sun-like stars have been more massive than Uranus, an icy giant about 15 times the mass of Earth. There is no direct proof that the new planet is rocky; however, its low mass would not allow it to retain gas as Jupiter does. Three other potential rocky planets have been found, but they orbit a pulsar—a burnt-out, pulsating star.

Located 15 light-years away in the direction of the constellation Aquarius, the newly discovered Earth-cousin orbits the star Gliese 876. The new planet is so close to the star that its surface is a scorching 400 to 750 degrees Fahrenheit. "It's too hot for liquid water," Butler said. "That tends to lead us to the conclusion that the most probable composition of this thing is like the inner planets of this solar system—a nickel-iron rock, a rocky planet, a terrestrial planet."

Gliese 876 is an M dwarf, a small, red star and the most common type of star in the galaxy. At about one-third the mass of the Sun, it is the smallest star around which planets have been discovered. Butler and Geoff Marcy, the co-leader of the planet-hunting team, detected the first planet there in 1998. It is a gas giant about twice Jupiter's mass. In 2001 the team reported a second gas giant about half Jupiter's mass. The two are in resonant orbits, with the outer planet orbiting the star in 60 days, twice the period of the inner giant planet.

"The planet's mass could easily hold on to an atmosphere," noted Gregory Laughlin, a team member and assistant professor of astronomy at U.C. Santa Cruz. The team will continue to monitor Gliese 876 while they look for other terrestrial planets among the 150 or more M dwarf planets they regularly observe.

"So far we find almost no Jupiter-mass planets among the M dwarf stars we've been observing, which suggests that, instead, there is going to be a large population of smaller-mass planets," Butler concluded.

This research, conducted at the Keck Observatory in Hawaii, was supported by NSF, NASA, the University of California, and the Carnegie Institution. See http://exoplanets.org/gl876_web/gl876_graphics.html for more information.

(continued from page 4)

tuning forks that have the same tone. If you excite one, it gives a characteristic tone. If you bring the second fork close to the first one, it will also start to give you a tone even though they do not touch. This is resonance energy transfer."

FRET can track the form of proteins that specifically bind metabolites such as sugars and amino acids. It has been used in the Frommer lab to trace metabolite transport in live plants. A protein of interest is genetically fused with two differently colored tags made from variants of the jellyfish green fluorescent protein (GFP). The colored tags are placed at each end of the molecule, making a "biosensor." When the substance of interest binds to the sensor, the sensor backbone becomes reoriented, and the reorientation can be detected. Since light is a vibration, the resonance response occurs with two fluorescent dyes that have overlapping but slightly different colors—in this case cyan and yellow versions of GFP.

"We used a protein called ybeJ from the common bacterium *E. coli*," explained coauthor Loren Looger. "After fusion to the fluorescent proteins, we placed the sensor on the surface of rat hippocampal cells. The hippocampus is the part of the brain that is involved with emotional reactions, and it helps store learned information in memory. We stimulated the neurons and watched them secrete glutamate in response. We also saw the removal of the glutamate as the neurons returned to normal, ready to fire again."

"This is a tremendously exciting technology," remarked Frommer. "It's fascinating to see a tool that we are using in plant biology open new areas in neuroscience."

This work was supported by grants from the National Institutes of Health (NIH), the NIH Roadmap Initiative Metabolomics Technology Development, the Human Frontier Science Program, and the U.S. Department of Energy.

IN Brief

❶ Carnegie trustee David Swensen.

❷ Wes Huntress receives an honorary doctorate at Brown U.

Trustees and Administration

Trustee and astronomer **Sandra Faber** received the Medal of the Institut d'Astrophysique in Paris July 4 for her many contributions to astrophysics including her work on dark matter, the discovery of black holes at galactic centers, and the existence of large-scale motions in the expanding Hubble flow. The latter two projects were joint ventures with Observatories' Alan Dressler.

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About 200 astronomers gathered Aug. 8-12 at UC-Santa Cruz for a weeklong conference to honor three UCSC professors—astronomers George Blumenthal and **Sandra Faber** and physicist Joel Primack. The conference was organized to celebrate their 60th birthdays.

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❶ **David Swensen** has a new book out for the personal investor, *Unconventional Success: A Fundamental Approach to Personal Investment*. He was also cited as "among the best investors of his generation" for his investment strategy successes as Yale's chief investment officer in the July 2005 *Institutional Investor* magazine.

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Carnegie president **Richard Meserve**, who clerked for Justice Harry Blackmun, spoke at a seminar at the Woodrow Wilson International Center in May about the biography *Becoming Justice Blackmun,* by Linda Greenhouse. Greenhouse, along with U.S. Court of Appeals Judge Merrick Garland, also participated in the seminar. Meserve spoke at a forum on nuclear safety sponsored by the OECD at the Nuclear Energy Agency Safety Regulation Forum 2005 in Paris in June. Also in June, he introduced an event sponsored by the Atomic Heritage Foundation focusing on the recent biography of Robert Oppenheimer by Kai Bird and Martin Sherwin. On July 4 he spoke at the Energy Forum sponsored by the Aspen Institute in CO. Meserve also served on the committee of the National Academies of Sciences and Engineering that authored the report *Strengthening Long-Term Nuclear Security: Protecting Weapon-Usable Material in Russia,* released in July.

Embryology

Marnie Halpern joined the Federation of American Societies for Experimental Biology science policy committee as the Society of Developmental Biology representative.

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Allan Spradling's lab welcomed HHMI fellow **Todd Nystul** (Fred Hutchinson Cancer Research Center), who is studying somatic stem cells in the *Drosophila* ovary and their role in ovarian cancer.

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The Spradling lab's **Toshie Kai** is now at National U. of Singapore.

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Janet Chang, a master's candidate in Joe Gall's lab, received a M.Sc. in cellular and molecular biology from Johns Hopkins U. She has been admitted to the Ph.D. program at SUNY-Stony Brook.

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New Hopkins graduate students **Courtney Hoshibata** and **Robyn Goodman** joined Marnie Halpern's lab, as did postdoc **Dan Gorelick** (Ph.D., Johns Hopkins Medical Institutions). Postdoc **Christian Brösamle** is now at U. Munich. **Joshua Gamse** left to start his own lab at Vanderbilt U.

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Anna Hei Chan (NIH) is a new postdoctoral fellow in the Zheng lab, and **Shusheng Wang,** formerly from the Johns Hopkins Medical School and MetaMorphix Inc., is a new research associate. **Kan Cao,** who graduated from Hopkins, is a postdoc at NIH.

Geophysical Laboratory

❷ **Wes Huntress** received an honorary doctorate at Brown U. on May 29 for his "distinguished career, accomplishments, and contributions to the

First CDAC Summer School a **Great Success**

Thirty-three graduate students and postdoctoral researchers from around the country attended the first Carnegie/DOE Alliance Center Summer School, June 1-3, at the Advanced Photon Source at Argonne National Laboratory. Sessions were taught by leading scientists from academia and the national labs. Lectures explored the chemical and physical fundamentals of matter at high densities, and demonstrated how static and dynamic experiments, along with condensed-matter theory, can provide a means to understand the behavior of matter under extreme conditions.

Presentations were made within the context of key materials and measurement capabilities crucial to stewardship of stockpiles and the missions of the National Nuclear Security Administration (NNSA) Labs. Because students came from other institutions besides CDAC partner universities, the program enhanced the alliance between DOE/NNSA and academia.

CDAC Summer School students came from universities throughout the U.S. Of the 33 students, 11 were female and 17 were foreign citizens.

❸ Robert Hazen (right) and NASA Astrobiology Institute director Bruce Runnegar participate in a field trip to the KT boundary in northern Spain.

❹ Yingwei Fei and his daughter Jennifer at the Great Wall of China.

academy, science, and the exploration of space . . . ”

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Ho-kwang (Dave) Mao presented a lecture at the Aminoff Symposium, “Studies of Solid Materials at High Pressures and Temperatures,” June 9-10 in Stockholm.

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❸ **Robert Hazen** attended Goldschmidt 2005, the annual meeting of the Geochemical Society, in Moscow, ID, and chaired the spring council meeting of the Mineralogical Society of America. He was also a guest editor on a special issue on the origin of life for the new geochemistry periodical *Elements*, and participated as one of four faculty members at the NASA Astrobiology Summer School in Santander, Spain, July 9-16. Carnegie Fellow **Rebecca Martin** attended as a student.

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Russell Hemley gave an invited talk at Howard U. in Washington on Feb. 11 and spoke in Orlando for Synchrotron Studies of Materials at Extreme Conditions Pittcon 2005, Feb. 27-Mar. 4. He spoke at the Finnish Physical Society on Mar. 16 in Helsinki and was invited to speak at the APS Mar. meeting in Los Angeles. Hemley also spoke at the Joint 20th AIRAPT - 43rd EHPRG International Conference on High Pressure Science and Technology in Karlsruhe, Germany, June 27-July 1.

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❹ **Yingwei Fei** organized an international symposium, “Frontiers of Earth Sciences,” in Guangzhou, China, on June 20-25. He also gave a lecture on phase transformations in the Earth’s mantle at Peking U. and a seminar on Mars exploration at Zhejiang U.

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Chih-Shiue Yan gave two talks at the 8th Applied Diamond Conference, NanoCarbon 2005, Argonne National Laboratory, May 15-19. He also spoke at the 10th International Conference on New Diamond Science and Technology, AIST, Tsukuba, Japan, May 11-14.

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Yang Ding and **Haozhe Liu** were promoted from postdoctoral fellows to research scientists on July 1.

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Postdoc **Olga Degtyareva** spoke at the APS Mar. meeting in Los Angeles. She also spoke at the third meeting on Study of Matter at Extreme Conditions held in Miami in Apr., and at the Fourth International Alloy Conference on the Greek island of Kos in June.

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Aravind Asthagiri, postdoc in the Cohen lab, left GL June 30 for U. Florida-Gainesville.

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Postdoc **Jung-Fu Lin,** who worked with Russ Hemley, left July 15 for Lawrence Livermore National Lab.

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Li Zhang (predoc in the Fei lab) returned to Southwest Jiaotong U., Sichuan, China.

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Visiting scientist **Takuo Okuchi** left Apr. 18 for the Graduate School of Environmental Studies, Nagoya U., Japan.

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Dimitri A. Sverjensky (Dept. Earth and Planetary Sciences, Johns Hopkins) is a visiting investigator working with Bob Hazen.

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❺ New arrivals at GL include **Guoyin Shen,** project manager at HPCAT beginning Sept. 1; **Szczesny (Felix) Krasnicki,** senior engineer for the CVD diamond project; visiting investigator **Jinyang Chen** from China; postdoctoral fellow **Hikaru Yabuta** from Japan, who is working with George Cody; postdoc **Jan Vorberger** from Germany to work with Burkhard Militzer; and **Susan Southard,** the new grants manager at GL. She is an alumna of Chesapeake College.

Global Ecology

Chris Field attended a meeting of the Intergovernmental Panel on Climate Change in Cairns, Australia, Mar. 12. He and Stephen Schneider represented the Stanford faculty on an expert panel for the National Geographic series *Strange Days on Planet Earth*. On Apr. 6 he spoke to the Union of Concerned Scientists on how future global warming may affect California. Field shares part of a proposal that will receive an average grant of $128,000 from 2005 to 2007 from the Stanford Institute for the Environment to study the reintroduction of the Bay Checkerspot butterfly to Stanford lands.

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On July 1 **Ken Caldeira** became the newest member of the staff. He is from the Climate and Carbon Cycle Modeling Group at the Lawrence Livermore National Laboratory (see page 12).

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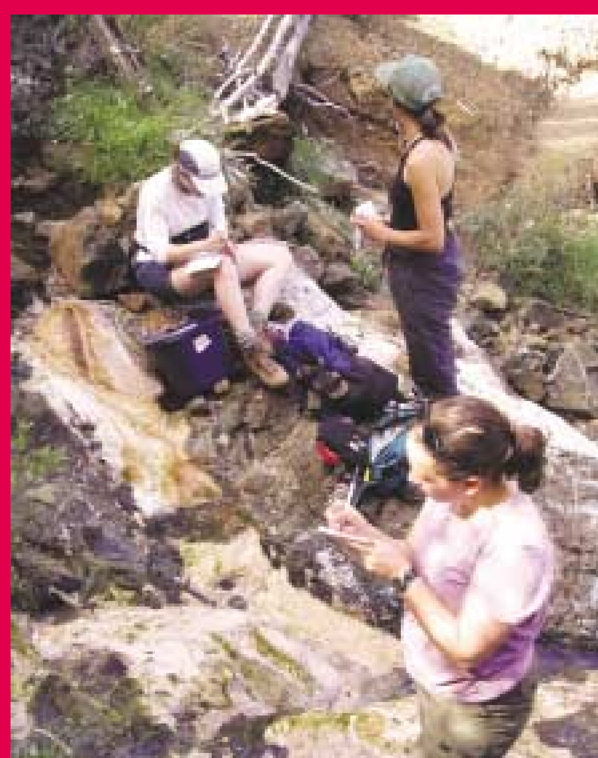
On June 24 **Jennifer Eigenbrode, Rachel Erdil,** and **Penny Morrill** in Marilyn Fogel’s lab set off for The Cedars, a barren region in Sonoma County, CA, where reduced, ultrabasic springs bubble with hydrogen and methane gases. Morrill sampled the bubbling gases to decipher their abiogenic and/or biogenic origins using compound specific isotope analysis. Erdil and Eigenbrode collected liquid samples for dissolved and particulate organic matter, and solid samples to determine the carbon cycling adjacent to and in the springs.



Clockwise from top left, GL scientists Penny Morrill, Jennifer Eigenbrode, and Rachel Erdil take notes at the mineral springs complex, which contains one the most basic and reduced springs at The Cedars.

❺ Susan Southard is the new grants manager at GL.

❻ Stanford graduate students Monica Stein and Marc Nishimura, shown with thesis advisor Shauna Somerville, completed their Ph.D. programs in May. Monica will continue studies of disease resistance in Shauna's lab until the end of the year. Marc will start a postdoctoral position in Jeff Dangl's lab at U. North Carolina.

On Mar. 29-30 **Greg Asner** gave a presentation before the World Bank on selective logging and deforestation, and on Mar. 31 he appeared before the U.S. Senate subcommittee hearings on satellite monitoring of tropical regions. His lab recently acquired a new LIDAR scanner, which can be used over large areas for rapid measurements of plant dimensions.

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In Apr. **Joe Berry** and **Larry Giles** installed CO_2 instruments to continuously measure air at the top of a 20-meter tower in Kruger Park, South Africa. Flasks of air and water vapor are shipped back to Carnegie for analysis. It is the first of at least three packages to be installed across Africa to obtain improved estimates of the carbon balance there.

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Adam Wolf, who will join the Berry lab as a Ph.D. student, was awarded a NASA Earth System Science Graduate Fellowship.

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Ulrike Seibt, a Marie Curie Fellow in the Berry lab, attended the first International Postdoctoral Network for Earth System Science workshop and the NCAR Climate Systems modeling workshop, both held in June in Breckenridge, CO.

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Field lab's **Yingping Wang,** associated with the International Program for Carbon-flux Modeling, is visiting until late Jan.

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Field lab graduate student **Jason Funk** is in New Zealand from June through Nov. collaborating with researchers to predict changes in agricultural land use from market price changes and to study how decision-making processes vary among landowners, many of whom are Maori tribesmen.

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Elsa Cleland left the Field lab for a postdoc position at the National Center for Ecological Analysis and Synthesis.

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Maoyi Huang (Ph.D., UC-Berkeley) joined the Asner lab to work on carbon cycle analysis of land-use/climate interactions.

Observatories

In Mar. **Wendy Freedman** was elected a member of the Astronomy and Astrophysics Advisory Committee. She was also recently elected a member of the board of trustees, Scripps College, Claremont, CA. Freedman attended the first meeting of the Dark Energy Task Force in Arlington, VA, on Mar. 22 and 23 and was invited by the MIT physics department to speak at a colloquium on Mar. 31. Freedman is a member of the External Advisory Board for the Kavli Institute for Cosmological Physics and attended the June 1-2 meeting at U. Chicago.

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Pat McCarthy gave a talk at the First Light and Reionization meeting at UC-Irvine; a talk at the Lawrence Livermore National Laboratory and at U. Washington; and he attended the AURA Observatories Council annual meeting. McCarthy also joined the publications board of the American Astronomical Society.

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July 20-24 **Alan Dressler** was invited to speak at Leiden Observatory, the Netherlands, and the Kapteyn Institute in Groningen as part of the Nova Seminars funded by the Dutch Research School for Astronomy and Astrophysics.

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Luis Ho gave a colloquium at Harvard and Boston universities and an invited talk, "The Paradoxes of Massive Black Holes: A Case Study in the Milky Way," at the meeting held at the Kavli Institute for Theoretical Physics. He visited the Very Large Array in New Mexico and attended the conference "The Origin of the Hubble Sequence," on Vulcano Island, Sicily.

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Research associate **Jon Fulbright** talked about "The Formation of the Galactic Bulge: The Stellar Abundance View" on June 27 at UC-Santa Cruz.

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Carnegie Fellow **Jeremy Darling** gave an invited colloquium at New Mexico State U. in Mar.

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Carnegie Fellow **Kurt Adelberger** gave an invited talk at the IAU Colloquium 199, "Probing Galaxies through QSO Absorption Lines."

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Scientific visitor **Christopher Sneden** (U. Texas) collaborated in June-July with **Andrew McWilliam, George Preston, Steve Shectman, Ian Thompson,** and Carnegie Fellow **Inese Ivans** on heavy metals in extremely metal-poor stars of the galactic halo.

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Edwin Turner (Princeton U.) was a scientific visitor during July and presented a colloquium.

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Carnegie Fellow **Ivo Labbé** gave a colloquium at the Observatories Mar. 8 and an invited talk at Ringberg Castle, Germany, on Mar. 30. He also gave two talks in early June at the IRAC GTO meeting at CfA.

Plant Biology

Chris Somerville presented the seminar "Genetic Dissection of Cell Wall Structure and Function" at U. British Columbia in Vancouver on Apr. 12; a talk at U. Iowa on May 16; and a workshop sponsored by U.S. DOE in Washington, DC, on June 13. He also presented the Keynote Symposium at the annual *Arabidopsis* meeting in Madison, WI, on June 15 and a talk at the BIO meeting in Philadelphia on June 22. On July 5 he presented the annual Woolhouse Lecture at the John Innes Institute in Norwich, England.

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❻ **Shauna Somerville** presented a seminar, "Genetic Dissection of Non-host Disease Resistance," at U. British Columbia on Apr. 13 and at Washington State U. on Apr. 27.

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Winslow Briggs gave a seminar at Yale in Apr. His group presented three posters on blue light receptors in plants, fungi, and bacteria at the annual meeting of the American Society of Plant Biologists. In Jan. Wiley released the *Handbook of Photosensory Receptors*, with chapters written by former Briggs lab postdocs **John Christie** and **Trevor Swartz** with Briggs. Editors were John Spudich and Winslow Briggs.

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Zhiyong Wang gave a seminar, "Brassinosteroid Signal Transduction: From Receptor Kinases to Transcription Factors," at the Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, Beijing, on Mar. 16, and at UC-Davis on May 27.

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Wolf Frommer presented a plenary talk at the Keystone Symposium on Plant Cell Signaling: In vivo and Omics Approaches, held Feb. 1-6 in Santa Fe, NM. He also gave a talk at U. Arizona, Tucson, on Mar. 21 and attended the 22nd Annual Missouri Symposium, Genomics and Beyond: Frontiers in Plant Biology on Apr. 27-30, where he presented a plenary talk. On June 2 he spoke at the Free U. of Brussels on "High Resolution Technologies for High Content Metabolomics and Functional Genomics." He presented the same talk at the HFSP meeting in Risø, Roskilde, Denmark.

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Devaki Bhaya gave a talk at the International Conference on Microbial Genomes, held in Halifax in Apr., and a talk at the Gordon Conference on Photosynthesis in July.

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Hae-Young Cho (U. Ulsan, Korea) joined the Briggs lab as a predoctoral research associate.

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Antoinette Sero joined Shauna Somerville's lab as a lab assistant on Feb. 25. **Jean Adams** joined as lab assistant for three months.

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Postdoc **Florence Mus** (Aix Marseille II U., France) joined the Grossman lab Apr. 5. Postdoc **Shaun Bailey** (U. Sheffield, U.K.) arrived on May 7.

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The Frommer arrivals include postdocs **Thijs Kaper** (U. Groningen, Netherlands) on Apr. 1; **Dominique Loque** (U. Hohenheim, Germany) on Apr. 1; and **Hitomi Takanaga** (Brigham and Women's Hospital, Harvard Medical School) on June 1. **Leonid Kozhukh** joined the lab as a lab assistant on June 16.

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New arrivals at Sue Rhee's TAIR group are **Aleksey Kleytmann** as assistant curator on Feb. 1 and **Joseph Filla** as systems administrator on Feb. 16. On

❼ Plant Biology interns from left to right are Michael Jin, Astasia Meyers, Aydin Golibgar, Agnes Harms, Blaise Hamel, and Ryan Pham.

Mar. 1 **Jon Slenk** rejoined the department as TAIR senior programmer. On May 2 **Daniel Maclean** arrived from U. Cambridge, U.K., to begin his postdoc.

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The Bhaya lab welcomed lab assistant **Renee Halbrook** on Mar. 1.

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Jennifer Johnson, grant administrator, departed Apr. 8. **Susan Cortinas** left her bookkeeping position to fill that vacancy.

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Renee Wang joined the staff on Apr. 25 as the AP specialist.

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Matthew Jobin left the Grossman lab on May 31 to return to Canada to complete his Ph.D.

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On June 30 **Jennifer Milne** left the Chris Somerville lab for a postdoc at Stanford. **Ginger Brininstool,** postdoc in the Chris Somerville lab, and **Steve Pollock,** an NIH Fellow in the Grossman lab, departed for Louisiana State U.

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Postdoc **Samuel St. Clair** left the Shauna Somerville lab for a postdoc at UC-Berkeley.

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The Frommer lab had two departures. **Marcus Fehr,** a postdoc, returned to Germany on Apr. 15 for a position in industry. **Hong Gu,** a predoctoral student, departed for Denmark to resume his studies at Risø National Laboratory in Roskilde.

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Rachael Huntley, a postdoc in the Barton lab, departed July 5 for home in England.

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❼ The department employed the following summer interns under the supervision of **Leonore Reiser: Iris Law** and **Shirin Rahmanian** (Grossman lab, funded by NSF); **Blaise Hamel** (Grossman lab); **Aydin Golibgar** and **Ryan Pham** (Rhee/TAIR group); **Matthew Woloszyn** (Chris Somerville's lab); **Michael Jin** and **Astasia Meyers** (Shauna Somerville's lab); and **Agnes Harms** (Frommer lab).

Terrestrial Magnetism

❽ **Vera Rubin** was awarded an honorary Doctor of Science degree by Princeton U. in May. The ceremony was led by university president Shirley Tilghman. Also in May, Rubin spoke to three eighth-grade science classes at the Key Charter School in Washington, DC. In July she appeared on an AAAS panel to celebrate the 125th anniversary of *Science* magazine.

❽ Vera Rubin (far right) stands with Princeton president Shirley Tilghman (middle, front) and other recipients of the honorary Doctor of Science degree.

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Sean Solomon co-convened and delivered a paper in a special session on "The Exploration of Mercury" at the 2nd Annual Meeting of the Asia Oceania Geosciences Society, held in Singapore in June. The MESSENGER spacecraft, for which Solomon serves as principal investigator, was directed toward its eventual encounter with Mercury by an Earth flyby on Aug. 2. Also in Aug., Solomon served as an external reviewer for the School of Earth and Environmental Sciences at Seoul National U., Korea.

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In May **Alan Boss** delivered the opening talk at the Space Telescope Science Institute's Symposium on "A Decade of Extrasolar Planets around Normal Stars," in Baltimore. **Sara Seager** also gave a talk at this meeting. Later in May, Boss spoke at the retirement symposium for John Wood, held at Harvard U., and delivered the monthly Director's Colloquium at the Los Alamos National Laboratory. In June he presented the final summary talk on the interpretation of observations of extrasolar planetary systems at the Gordon Research Conference on Origins of Solar Systems, held at Connecticut College, where postdoctoral fellow **Hannah Jang-Condell** was in attendance. In July Boss delivered several lectures on the formation of planetary systems at the Kobe International Summer School of Planetary Science, held on Awaji Island in Japan, and he spoke at the Workshop on Habitability of Planets Orbiting M-Stars, held at the SETI Institute, in Mountain View, CA. DTM postdoctoral associate **Maggie Turnbull** participated in these events.

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Among those in attendance at the 15th Goldschmidt Conference in Moscow, ID, were **Rick Carlson, Steve Shirey,** postdoctoral fellows **Katie Kelley** and **Maria Schönbächler,** and former postdoctoral fellows **Ambre Luguet, Petrus le Roux,** and **Mark Schmitz.** In addition, postdoctoral associates **Alison Shaw** and **Henner Busemann** gave invited talks.

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In May **Erik Hauri, Katie Kelley,** and **Alison Shaw** gave talks at a workshop on "Inclusions in Minerals and Processes in the Earth's Mantle," hosted by the Max Planck Institute in Tegernsee, Germany.

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Larry Nittler presented a poster at the American Astronomical Society meeting in Minneapolis in May. He also gave an invited talk at the annual Microscopy and Microanalysis conference in Honolulu in July.

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Sara Seager spoke at the International Astronomical Union's Symposium 231: "Astrochemistry–Recent Successes and Current Challenges," held in Asilomar, CA, in Aug. Seager also gave a Sept. colloquium at the Space Telescope Science Institute.

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Both **Paul Silver** and C. V. Starr Fellow **Taka'aki Taira** presented their work at the 2005 Joint Assembly Meeting of the American Geophysical Union, held in New Orleans in May. **Selwyn Sacks, Sean Solomon,** and MESSENGER Fellow **Catherine Hier-Majumder** also attended. Later in May, Silver conducted an active seismic source experiment at the San Andreas Fault Observatory at Depth drill site along the Parkfield segment of the fault, and in June he attended the IRIS/UNAVCO annual meeting held in Stevenson, WA, with Harry Oscar Wood Fellow **Linda Warren.**

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In Sept. postdoctoral fellow **Maud Boyet** gave an invited talk at the "Earth's Mantle Composition, Structure and Phase Transitions" workshop held in Saint Malo, France.

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James Cho gave invited colloquia in two departments at Seoul National U. in June. He also gave a talk in July at a workshop "The Role of Volatiles and Atmospheres on Martian Impact Craters," held in Laurel, MD.

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Catherine Hier-Majumder arrived in Apr. as a MESSENGER Fellow, working with Director Sean Solomon. While at Carnegie, she is collaborating with Alain Vincent of U. Montreal and David Yuen of U. Minnesota on modeling finite Prandtl convection in three dimensions. Before joining DTM, Hier-Majumder was a postdoctoral researcher at the Lawrence Livermore National Laboratory. In June she presented a paper at the Gordon Research Conference, "Interior of the Earth," at Mount Holyoke College, MA, and also gave a talk at the Mantle Convection Workshop for Computational Infrastructure for Geodynamics in Boulder, CO. In July she gave a talk, "Finite Prandtl Convection," at both Yale and Brown and later presented an invited talk at the Virtual Laboratory for Earth and Planetary Materials, Minnesota Supercomputing Institute, U. Minnesota.

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Visiting investigator and former postdoctoral associate **Elizabeth Myhill** and her student **Justin Domes** (Marymount U.) began work in May with **Alan Boss** on testing and developing a new adaptive mesh hydrodynamics code (FLASH) for studying the formation of stellar and planetary systems.

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Predoctoral fellow **Tatjana Rehfeldt,** a Ph.D. student at the Johannes Gutenberg Universität in Mainz, Germany, arrived in May to work with **Rick Carlson.** Rehfeldt carried out Re/Os isotope analyses of ultramafic cumulate xenoliths from kimberlites of the Kaapvaal Craton in southern Africa.

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Hubble Fellow **Scott Sheppard,** with collaborators from U. Hawaii, announced the discovery of 12 new moons of Saturn. He also announced the discovery of only the second Neptune Trojan, which shares its orbit with Neptune and was discovered on the Magellan Baade telescope with IMACS. Sheppard gave an invited review talk on outer satellites of the planets and how they relate to asteroids, comets, and Kuiper Belt objects at the Asteroids, Comets, and Meteors conference in Brazil in Aug.

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In Aug. postdoctoral associate **Maggie Turnbull** joined the Arctic Mars Analogue Svalbard Expedition (AMASE) with several GL colleagues to explore the area from the perspective of remote sensing of microbial life. In Sept. she is visiting the Australian Center for Astrobiology to study the spectrum of Earthshine using data from the Anglo-Australian Telescope.

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Kaspar von Braun, a postdoctoral associate in the astronomy group, gave invited talks in Aug. at the Astrobiology Graduate Conference, La Jolla, CA, and at Caltech.

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❾ Georg Bartels at his retirement party June 13.

❾ After working in the department's machine shop for over 23 years, **Georg Bartels** retired at the end of June. A celebration was held in his honor on June 13. Bartels spent much of his time at DTM working with the geophysics group to build borehole strainmeters, which are installed worldwide. He also developed a device that is used to deliver the necessary volume of cement to couple the sensor to the rock in which it rests.

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In June **Michelle Brooks** joined DTM as a new administrative assistant after working in the Maryland House of Delegates. She has a strong background in Web site development and event planning.

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Oksana Skass resigned as the administrative assistant at DTM to devote time to raising her first child, born in Jan.

The latest group of summer interns were on campus from May to mid-August. At GL **Edward Banigan** (Georgetown U.) investigated equations of state of $MgAl_2O_4$ Spinel with Razvan Caracas. **Rachel Erdil** (Wellesley College) worked with Marilyn Fogel on dissolved organic matter in ultrabasic springs in Sonoma County, CA. **Gretchen Hartwig** (U. Wisconsin) studied sample-handling extraction for life analysis with Andrew Steele. Working with Heather Watson, **Katharine Johanesen** (Beloit College) studied the diffusion of Au in Fe and Fe-Ni alloys. **Elizabeth Littlefield** (Colby College) investigated the effects of water on the behavior of $MgSiO_3$ clinoenstatite at high pressure with Steve Jacobsen. Under Steve Gramsch's guidance, **Lisandra Rosario** (Universidad Metropolitana, San Juan) looked at the formation of the orthorhombic structure of $FeAlO_3$. **Jennifer Smith** (West Virginia U.) contributed to the Carnegie Legacy Project with Shaun Hardy. **Cathy Tarabrella** (West Virginia U.) studied crystal structures of CsCl and CsI under pressure with Olga Degtyareva. **David Weinberger** (Millersville U.) investigated the synthesis of hydrocarbon chains via natural-transition metal catalysts with George Cody.

At DTM, intern **Aditi Bhaskar** (Brown U.) analyzed data from two DTM seismometer deployments on the Tibetan Plateau and in the Yunnan Province, China, to identify variations in crustal and mantle structure along the plateau boundary with Paul Silver and Brian Savage. **Amanda Hughes** (Washington and Lee U.) studied the mechanisms of intermediate- and deep-focus earthquakes with Linda Warren. **Jennifer Ortega** (U. Missouri) assisted Sara Seager on developing models of the Archean Earth as an analogue to an extrasolar planet. **Erica Staehling** (Bucknell U.), with James Cho, studied magnetohydrodynamic shallow-water turbulence on a rotating sphere and its astrophysical applications. In addition, former intern **Sonali Shukla** (NYU) returned to continue her work with **Seager** developing models for extrasolar planets.

GL/DTM

The research files, notebooks, and scientific correspondence of the late DTM staff member **Louis Brown** were presented to the DTM archives by Brown's widow, Lore. The collection spans nearly 50 years of Brown's work in nuclear physics and geochemistry. Brown's extensive collection on the history of radar was donated to the Dibner Library of the History of Science and Technology at the Smithsonian Institution.

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Visiting investigator **Bruce Jakosky,** a regular visitor to DTM and GL for the last three years, returned to U. Colorado-Boulder in June.

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Ann Mulfort and **Jennifer Snyder,** Carnegie Legacy Project archivists, attended the annual meeting of the Society of American Archivists in New Orleans in Aug.

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Archivist **Kevin Stone Fries** completed a practicum at the campus archives this summer.

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A new volunteer, **Akiko Taira** (wife of C.V. Starr Fellow Taka'aki Taira), has joined the library staff.

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❿ Research staff members from both BBR departments enjoyed a potluck spring picnic over the Memorial Day weekend.

❿ Above, the Broad Branch Road campus picnic was held May 28.

Right, DTM won the semiannual Mud Cup Soccer Tournament against GL on July 15 with a 4-2 victory for the underdogs. Both teams pose after the game.

Carnegie Meets the $1.5 MILLION Kresge Challenge!

The capital campaign for the Maxine F. Singer Building project–the state-of-the-art research laboratory for the Department of Embryology in Baltimore–came to a successful close on July 1.

More than 230 individuals, foundations, and corporations contributed $20 million for the Carnegie project over the past five years. In 2003 the Kresge Foundation awarded Carnegie a pledge of $1.5 million, which was contingent upon Carnegie's success in raising the rest. The Singer Building campaign ended successfully just days before Kresge's summer 2005 deadline. "We are most grateful to the many individuals who, upon learning of the Kresge Challenge, made especially generous gifts to Carnegie to help us reach our goal," said Carnegie president Richard A. Meserve. "Now that the building campaign has been successfully completed, we look forward to stepping up our efforts to raise funds for other high-priority projects including the David Greenewalt Building at Broad Branch Road, Global Ecology's Carnegie Airborne Observatory, and the Giant Magellan Telescope project," he remarked.

Carnegie's developmental biologists moved into the newly completed Maxine F. Singer Building on the western edge of The Johns Hopkins University campus earlier this summer, leaving behind their old laboratory building, constructed in 1960, for use by the university. The new building is an extraordinary example of form and function, creating an unusually attractive environment for scientific research.

Maxine F. Singer, for whom the new Embryology building is named.

Carnegie Scientists **Honored**

Carnegie geneticist and 1983 Nobel Prize winner Barbara McClintock was honored with a U.S. Postal Service stamp earlier this year for her pioneering research into "jumping genes." McClintock was one of only four scientists chosen for the honor. She was also one of some 45 individuals over the last 100 years whose work was cited by *Science* magazine as a "Milestone of Science" in their poster issued for the magazine's 125th anniversary. Carnegie's Edwin Hubble, who discovered that the universe is vaster than was previously thought and that it is expanding, was also featured on the poster.

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