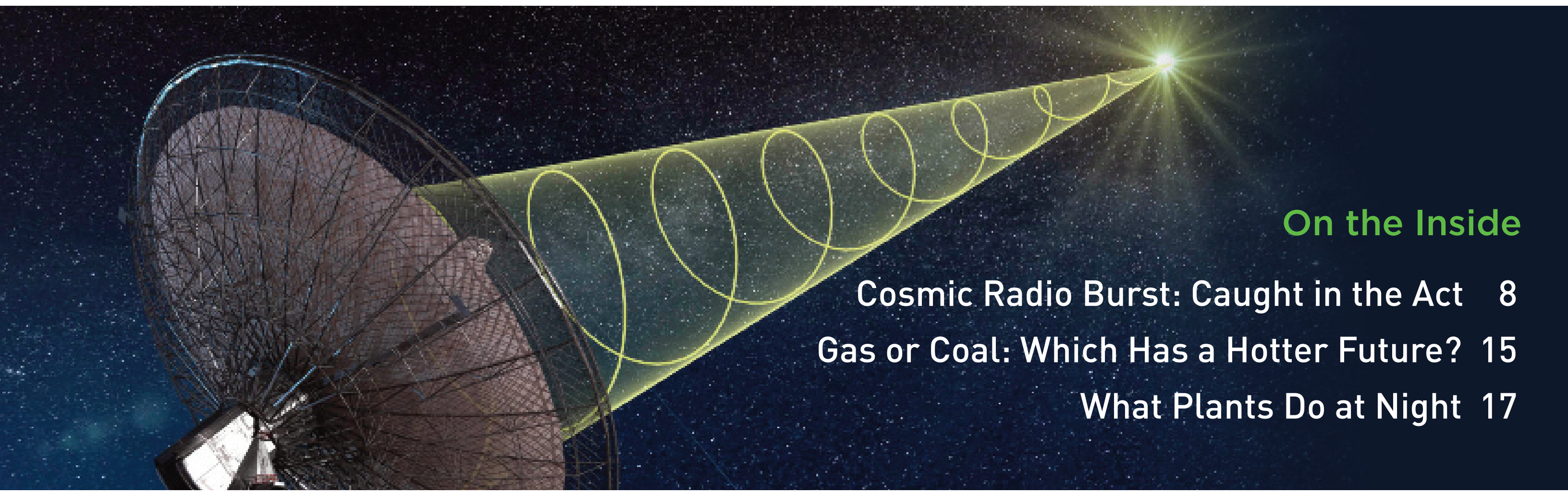
CarnegieScience

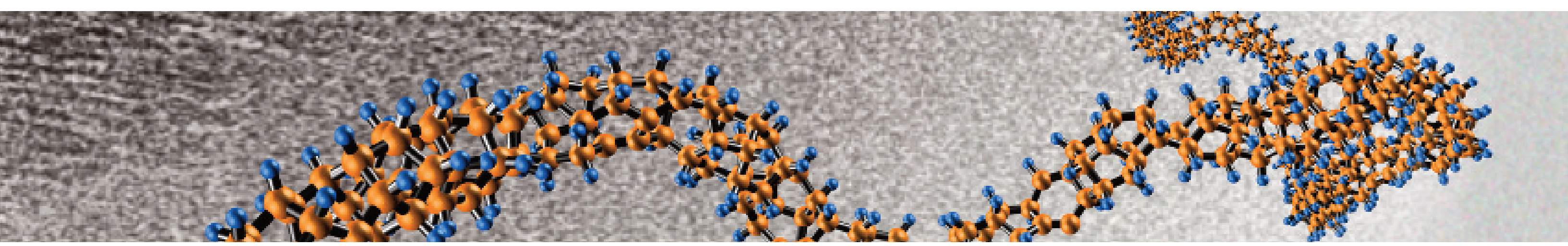
The Newsletter of the Carnegie Institution

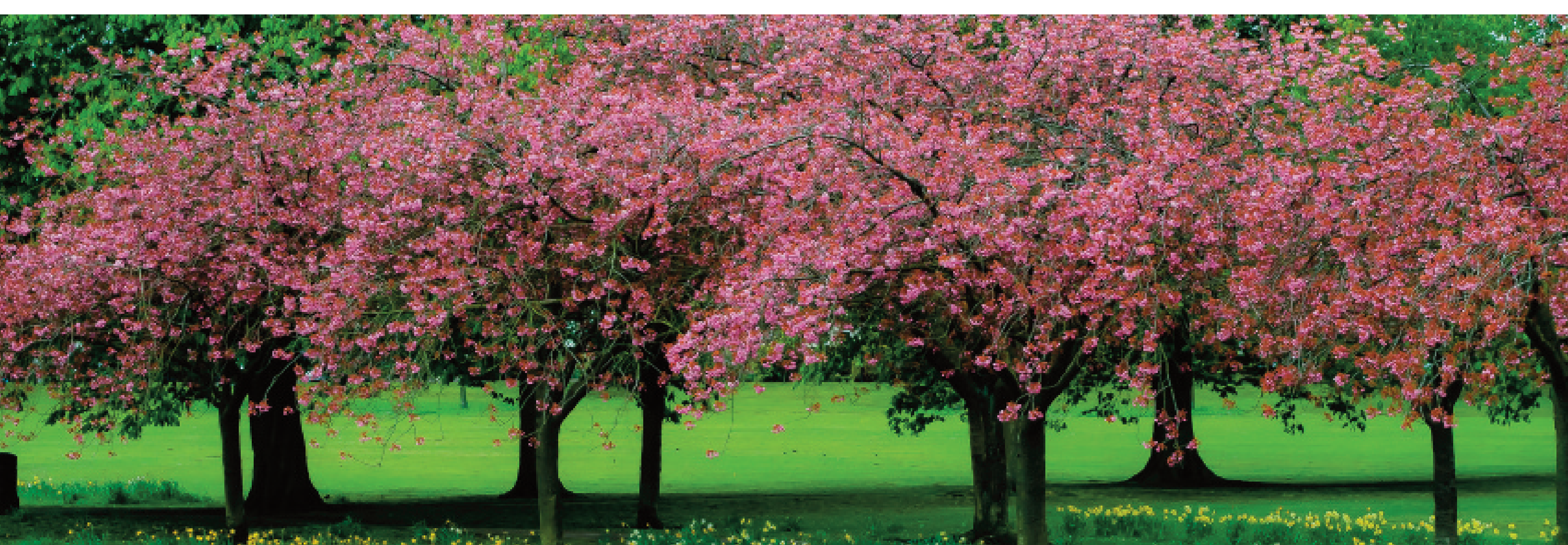
SPRING 2015

EMBRYOLOGY ◻ GEOPHYSICAL LABORATORY ◻ GLOBAL ECOLOGY ◻ THE OBSERVATORIES ◻
PLANT BIOLOGY ◻ TERRESTRIAL MAGNETISM ◻ CASE: CARNEGIE ACADEMY FOR SCIENCE EDUCATION



On the Inside





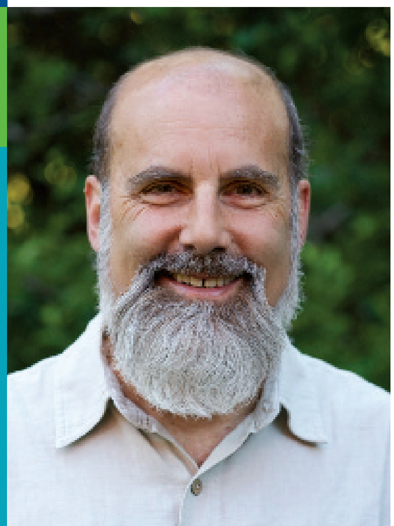
Carnegie Science

CARNEGIE INSTITUTION FOR SCIENCE

1530 P STREET, NW
WASHINGTON, D.C. 20005-1910
202.387.6400

LETTER FROM THE PRESIDENT

Why Study Extremes?



Hundreds of people enjoyed Doug Koshland's Capital Science Lecture at P Street on February 11, 2015, about how biologists use organisms with special properties to discover fundamental aspects of biology that are found in many or all life forms. His own research explores the ability of yeast, a single-celled fungus, to come back to life after it is dried—no mean feat and yet one that is taken for granted by all of us who buy packets of dried yeast for making bread (or beer).

Doug was a Carnegie Embryology staff member for 20 years before moving to UC-Berkeley to lead a department there. He credited the genesis of his yeast desiccation work to Carnegie's freedom to explore. His research is leading to new ideas about how cells can travel across remote deserts without canteens. This is far from an academic exercise, since it could be applied to learning how to better dry and recover blood cells, for example, to transform blood transfusion supplies or make seeds, often foodstuffs, last longer. Or maybe single-celled organisms from space traveled to our "shores" and survived desiccation. Doug referred to studies of tardigrade desiccation; these little animals can survive extreme temperatures below and above freezing, and the vacuum of space. As so often happens, studying mysteries of fundamental biology may lead to new ideas for medicine, agriculture, engineering, and life's origins.

Biologists often study organisms with exaggerated features. For example, humans with their overgrown frontal cortexes; bats that process sonar information with incredible speed; elephant seals who dive to pressures of more than 200 atmospheres; squids with giant neurons to record electrical impulses; flies and salamanders that have giant chromosomes; moths that detect single molecules of pheromones to find mates; worms and microbes at deep sea vents growing happily under enormous temperatures and pressures in seemingly toxic chemicals; chess players who can win 25 games at once, blindfolded; and bacteria that survive enormous pressures in the diamond anvils at Carnegie's Geophysical Laboratory. These organisms are heroes of a sort and tell us that much more is possible than we imagined.

At Carnegie, developmental biologists, astrobiologists, geologists, chemists, evolution scientists, and ecologists share their fascinations with extreme organisms. Almost invariably, the extremes are informative about more general properties of life. Giant chromosomes show the structures of normal chromosomes through a natural magnifying glass. Viruses deep in the Earth suggest ways that genetic information was transferred and changed in ancient times, and the chemistry and physics of extreme environments inform us about origins of Earth and life forms. In the future, I expect that Carnegie explorers, often with heroic effort, will expand their use of natural extremes to obtain extremely interesting insights into extremely important aspects of who we are and how things work.

Matthew Scott, *President*

Craig Barrett Elected to the Carnegie Board

Craig Barrett was elected to the Carnegie Board of Trustees at the Board's November meeting. He is chairman and president of BASIS Schools, Inc., an operator of charter schools in Arizona, Texas, and Washington, D.C., and he is a leading advocate for improving education in the United States. Barrett retired as chairman of Intel Corporation in May 2009 after serving in a variety of roles there for over thirty-five years.

Barrett earned a B.S., M.S., and Ph.D., all in materials science, from Stanford University between 1957 and 1964. After graduation, he joined Stanford University's Department of Materials Science and Engineering and remained there until 1974, rising to the rank of associate professor. From 1964 to 1965 Barrett was a NATO Postdoctoral Fellow at the National Physical Laboratory in the United Kingdom, and in 1972 he was a Fulbright Fellow at the Technical University of Denmark. He authored over forty technical papers about the influence of microstructure on the properties of materials and wrote a textbook on materials science, *The Principles of Engineering Materials* published in 1973.

Barrett is heavily involved with many educational organizations around the country. He is also vice chair of Science Foundation Arizona and cochair of the Lawrence Berkeley National Laboratory Advisory Board, among his numerous other leadership and advisory roles with organizations across the science, technology, business, government, and education spectrum. □

Timothy P. Doyle Joins Carnegie as COO

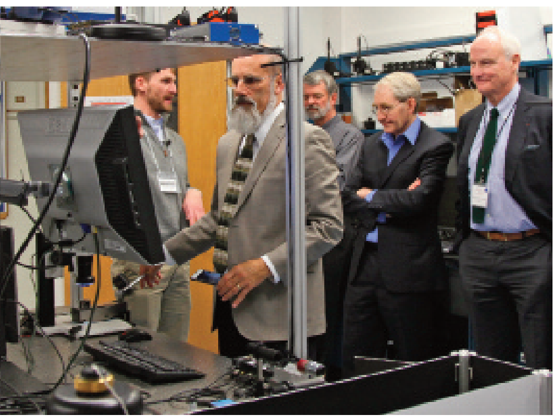
Timothy Doyle, Associate Dean for Finance and CFO for Harvard's School of Engineering and Applied Sciences (SEAS), has joined Carnegie as Chief Operating Officer.

Doyle has a unique blend of experience including complex administrative and financial organizations, private sector businesses, and most recently the research and education sectors. His diverse financial and operations background spans the areas of strategic leadership, financial systems and controls, budgeting and planning, and administration efficiency. This expertise is combined with strong leadership skills, developed early while serving in the United States Army as a commissioned officer through ROTC. Doyle was then a director with Rand McNally, where he led a staff of 240 to execute daily production operations; he also oversaw capital management, plants assets, and employee development.

Following the time spent in the military and publishing operations, Doyle moved into the financial services industry, where he served seven years as Vice President of Financial Operations with Fidelity Investments. He then transitioned into higher education working at Harvard University Press as Chief Financial Officer. Most recently, he became the Associate Dean for Finance and CFO in Harvard's School of Engineering and Applied Sciences.

Doyle received a B.S. in Marketing from Boston College, Carroll School of Management and an MBA with a concentration in International Finance and Operations from Suffolk University, Sawyer Business School in Boston. □

TRUSTEES MEET NOVEMBER 2014



(Top) Andrew Steele describes some of his work with the Rosetta mission to trustees on a tour.

(Bottom) Tim Strobel (far left) compresses water into a different form of ice. Carnegie president Matthew Scott (second from left) watches the crystal formation on screen as trustees Christopher Stone (second from right) and John Crawford (right) look on.

Touring the Geophysical Lab

The Carnegie Board of Trustees met at the Broad Branch Road campus, hosted by the Geophysical Laboratory, on November 20. Much of the first session of the board was an orientation to current research at the lab. Anat Shahar talked about her work with stable isotopes, variations of elements with different numbers of neutrons that do not decay into other elements. She explained how the ratios of these different isotopes could tell researchers about the pressure and temperature processes that formed planetary interiors and other bodies. Andrew Steele spoke about his work looking for life elsewhere in the Solar System and analyzing sources of carbon from samples such as meteorites. He also spoke about various space missions he has been involved with, including the European Space Agency's Rosetta comet mission and NASA's Sample Analysis at Mars (SAM) mission. The trustees broke into groups to tour labs and the high-pressure facility.

Sampling Science

The second day of the board meetings took place at the administration building, and it featured more scientific talks. José Dinneny of Plant Biology spoke about understanding how plant root systems sense water, nutrients, and environmental stresses, particularly the molecular process, and the new techniques his lab has developed. One technique is a custom imaging system to view root reactions over time. His research is important for learning how to develop plants that can withstand changing conditions, such as drought and salt stress.

Josh Simon of the Observatories talked about his research studying the chemistry of the first stars from some 13 billion years ago and the role of the Magellan telescopes at Carnegie's Las Campanas Observatory. He explained how the ages of stars can be determined by the elements they contain. The earliest stars had fewer and lighter elements. Newer stars create more elements in their cores, which are then expelled into space as the star explodes. He described the search for old stars in the Milky Way and in nearby dwarf galaxies.

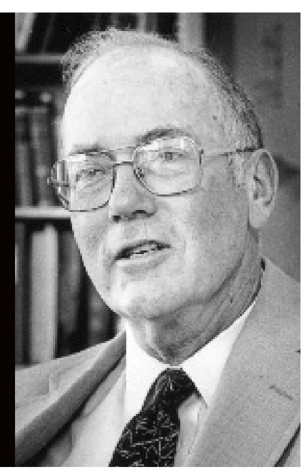
Yixian Zheng from Embryology spoke about her team's finding that the gradual reduction of a protein called lamin-B in the fat bodies of aging flies is the culprit behind fat body inflammation and the aging of the immune system. The results have potentially important implications for humans (see p. 6). Ronald Cohen of the Geophysical Laboratory discussed his work on solving problems in materials science and Earth science using so-called first principles calculations on some of the largest known computers. His predictions are substantiated with experiments.

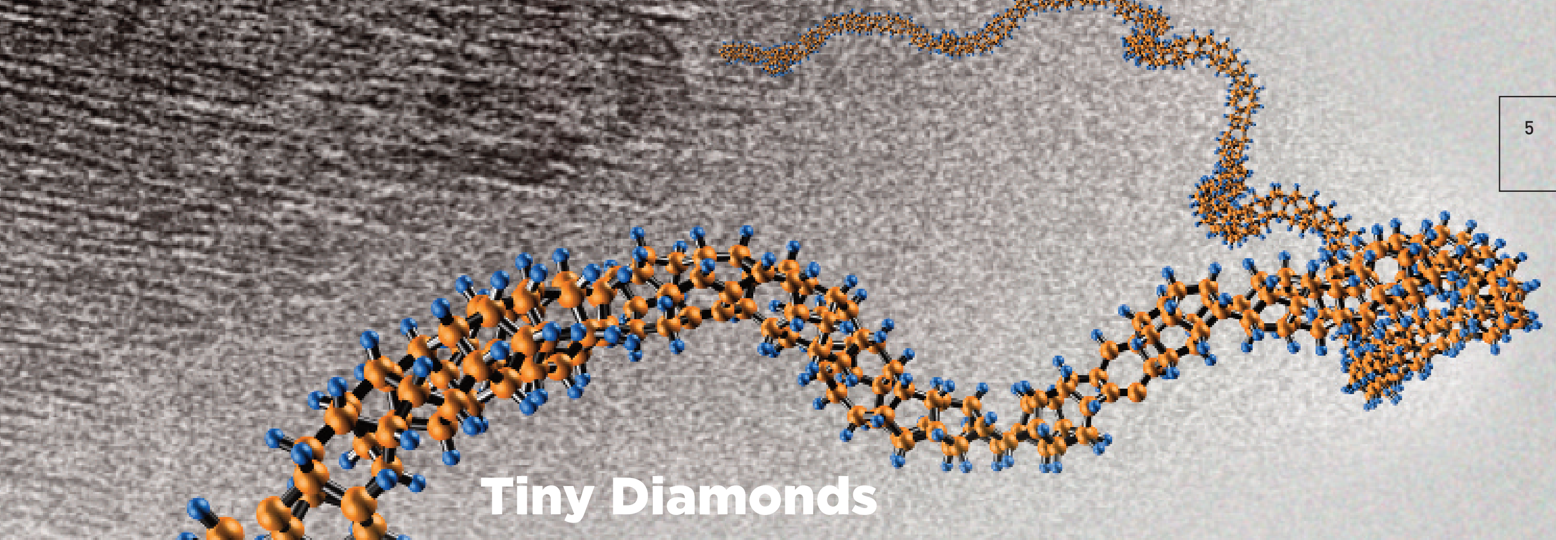
Geologist Steve Shirey spoke about diamond geology to understand Earth's deep mantle, including aspects of Earth's evolution. Small impurities encapsulated in the stones are in preserved form and reveal many processes from the past. Finally Chris Field, director of Global Ecology, talked about the acidification of Earth's oceans and their future. He described how more acidic oceans are affecting corals' ability to make skeletons and Ken Caldeira's experiments at One Tree Island of the Great Barrier Reef to understand the rate of carbonate uptake. Carbon dioxide is absorbed by seawater, reducing seawater pH and carbonate concentrations, the material necessary for shell and skeleton creation. □

Trustee Emeritus and Laser Inventor **Charles Townes Dies**

Nobel laureate and trustee emeritus Charles Townes died January 27, 2015, at the age of 99.

Townes joined the Carnegie board in 1965, one year after he shared the Nobel Prize in Physics with Alexander Prokhorov and Nikolai Basov for the development of the maser (acronym for microwave amplification by stimulated emission of radiation) and its better-known optical counterpart, the laser. He was dedicated to Carnegie and remained very active until recently. Townes was a professor emeritus of physics at UC-Berkeley. Over the last half century, his discoveries transformed the way we live our lives, by enabling or enhancing technology used in surgical devices, consumer electronics, data encoding, and communication networks. Townes received 31 honorary degrees and 38 awards, including the 2006 Vannevar Bush Award from the National Science Board—the oversight body of the National Science Foundation—and the 2005 Templeton Prize for contributions to "to affirming life's spiritual dimension." Townes is survived by his wife, Frances; daughters Holly Townes, Linda Rosenwein, Ellen Townes-Anderson, and Carla Kessler; and six grandchildren and two great grandchildren. □





Tiny Diamonds FORM ULTRATHIN NANOTHREAD

A team including Carnegie's Malcolm Guthrie and George Cody has, for the first time, discovered how to produce ultrathin "diamond nanothreads." These structures promise extraordinary properties, including strength and stiffness greater than that of today's strongest nanotubes and polymer fibers, and they have an array of potential applications, from fuel-efficient vehicles to the science fictional-sounding space elevator. *Nature Materials* published their work.

(Above) "Diamond nanothreads" promise extraordinary properties, including strength and stiffness greater than that of today's strongest nanotubes and polymers. The threads have a structure that has never been seen before and differs from diamonds' normal cubic structure.

Image courtesy Vincent Crespi lab, the Pennsylvania State University

(Left) Malcom Guthrie works with the Energy Frontier Research in Extreme Environments (EFree) Center headquartered at Carnegie's Geophysical Laboratory.

Image courtesy Malcom Guthrie

The team—led by John Badding, a chemistry professor at the Pennsylvania State University, and his student Thomas Fitzgibbons—used a specialized large-volume high-pressure device to compress benzene up to 200,000 times atmospheric pressure. At these enormous pressures, benzene spontaneously forms into long, thin strands of carbon atoms that are arranged like the fundamental unit of diamond's structure—hexagonal rings of carbon atoms bonded together—but organized in chains rather than in a full 3-D diamond lattice. The long polymer threads are made up of chains of carbon atoms bonded to each other. The threads are less than a nanometer in diameter, a never-seen-before structure.

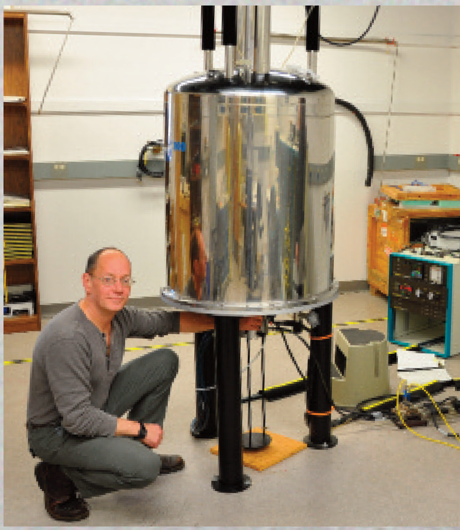
Benzene is a flat ring-shaped molecule containing six carbon atoms bonded to each other and to six hydrogen atoms. During the compression process, the normally flat benzene molecules stack together in a dense crystalline arrangement. After compression at high pressure, the resulting diamond-cored nanothreads are surrounded by a halo of hydrogen atoms. As the researchers slowly release the pressure, the benzene molecules unexpectedly react with each other, forming new carbon-carbon bonds with the carbon configuration of diamond but extending out as a long, thin nanothread. The team's discovery comes after nearly a century of failed attempts by other labs to compress separate carbon-containing molecules, such as liquid benzene, into an ordered, diamond-like nanomaterial. "We used the large high-pressure Paris-Edinburgh device at Oak Ridge National Laboratory to compress a 6-millimeter-wide amount of benzene—a gigantic amount compared with previous experiments," said Guthrie. "We discovered that slowly releasing the pressure after sufficient compression at normal room temperature gave the carbon atoms the time they needed to react with each other and to link up in a highly ordered chain of single-file carbon tetrahedrons, forming these diamond-core nanothreads."

The team is the first to coax molecules containing so-called aromatic carbon bonds to form larger-scale molecular structures in the shape of long, thin nanothreads. The thread's width is phenomenally small, only a few atoms across, hundreds of thousands of times smaller than an optical fiber, and more than 20,000 times smaller than average human hair.

The scientists confirmed the structure of their diamond nanothreads using a number of advanced techniques. Parts of these first diamond nanothreads appear to be somewhat less than perfect, so improving their structure is a continuing goal of the program, as is figuring out how to make the nanothreads under more practical and larger-scale conditions. Other coauthors include Enshi Xu, Vincent Crespi, and Nasim Alem of Penn State and Stephen Davidowski of Arizona State University. □

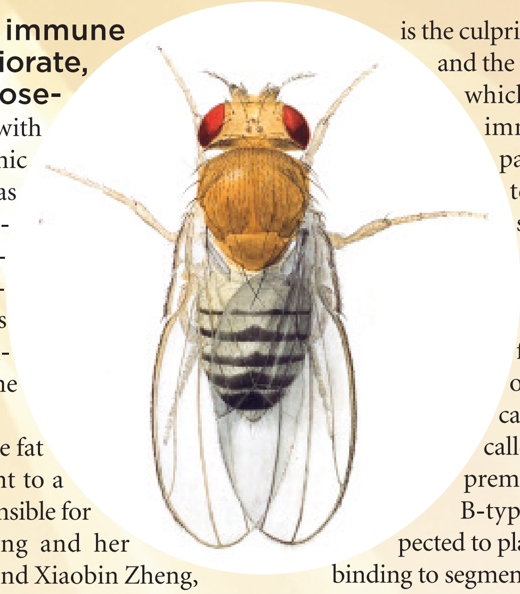
(Below) George Cody, acting director of the Geophysical Laboratory, is shown in his lab.

Image courtesy George Cody



This research received financial support as part of the Energy Frontier Research in Extreme Environments (EFree) Center and the Energy Frontier Research Center funded by the U.S. Department of Energy.

ACHING AND AGING:
Key Age-Related Protein Found



As animals age, their immune systems gradually deteriorate, a process called immunosenescence. This is associated with systemic inflammation and chronic inflammatory disorders, as well as with many cancers. The causes underlying this age-associated inflammation are poorly understood. Work from Yixian Zheng's lab sheds light on one protein's involvement in suppressing immune responses in aging fruit flies.

Insects have an organ called the fat body, which is roughly equivalent to a mammal's fat and liver. It is responsible for many immune functions. Zheng and her team, Carnegie's Haiyang Chen and Xiaobin Zheng, found that the fruit fly fat body experiences a great deal of inflammation in aged flies.

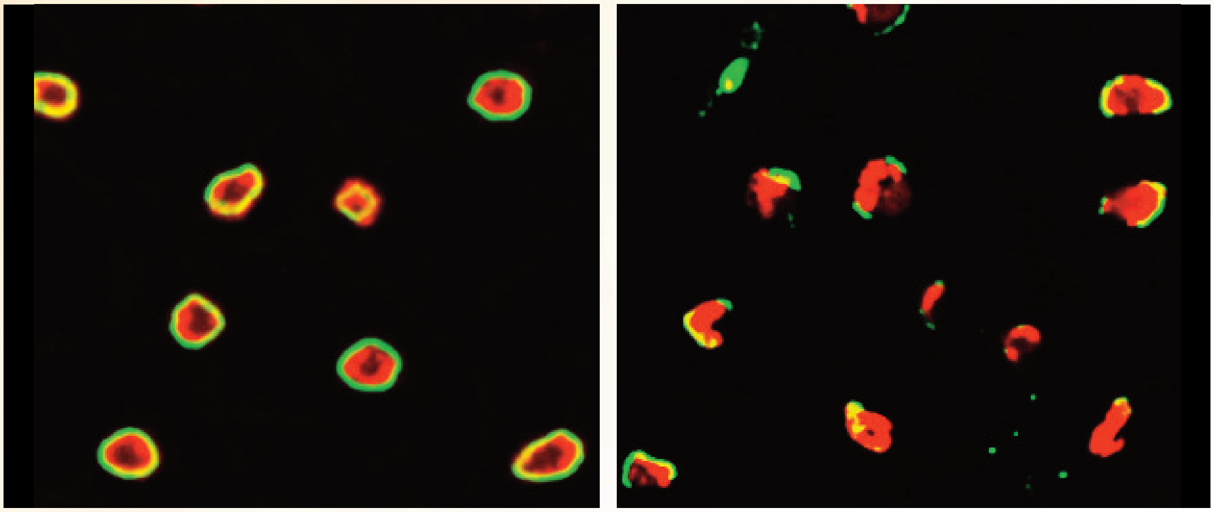
These inflamed fly fat bodies secrete proteins that lead to a reduction in the immune response of the gut. This reduction causes the gut's stem cells to undergo excessive division and inappropriate differentiation, creating a condition called hyperplasia that shares features with the precancerous polyps found in human guts.

Zheng and her team found that the gradual reduction of a protein called lamin-B in the fat bodies of aging flies is the culprit behind fat body inflammation and the resulting hyperplastic gut, all of which falls under the umbrella of immunosenescence. Lamin-B is part of the lamin family of proteins, which forms the major structural component of the material that lines the inside of a cell's nucleus. Lamins have diverse functions, and they are found in an array of tissues and organs. In humans, diseases caused by mutations in lamins are called laminopathies and include premature aging.

B-type lamins have long been suspected to play a role in gene suppression, by binding to segments of DNA. The team's work revealed that when the fruit fly fat body was depleted of lamin-B, the normal suppression of genes involved in the immune response is reversed, just as it would be in response to bacterial infection or injury, but in this case there is no apparent infection or injury. The unsuppressed immune response initiates the inflammation and resulting gut hyperplasia. These findings have implications for mammals as well as for insects, as lamin-B might play an evolutionary role in suppressing inflammatory genes in a variety of animal immune organs. □

(Above left) The fruit fly *(Drosophila melanogaster)* is used extensively in genetics research as a model organism.

Yixian Zheng



This image shows a comparison of lamin-B in the fat bodies of 10-day-old (left) and 50-day-old fruit flies.
Image courtesy Yixian Zheng

Cell published the work in November.

A Senior Scholar Award from the Ellison Medical Foundation and the National Institutes of Health supported this work.

Shipboard Lab Mimics Deep-Sea

Carnegie's Dionysis Foustoukos wants a direct view of life functioning in the extreme conditions of the deep ocean, as well as of the distribution of life in the deep biosphere. He collects microorganisms from submarine volcanoes and uses novel, shipboard experimental tools and techniques, including a high-pressure bioreactor that was invented at Carnegie's Geophysical Lab, to culture them at extreme pressures—matching those found four miles deep in the ocean.

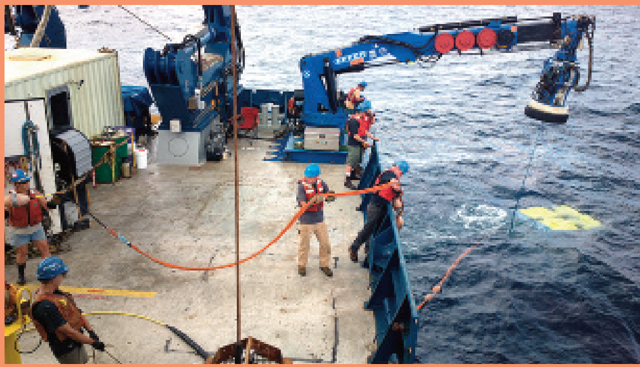
Foustoukos' findings offer a detailed look at the biological activity deep below the ocean's surface, where life thrives despite darkness and a scarcity of nutrients, as well as at the chemistry cycles underlying the distribution of those nutrients. His experiments simulate these conditions and the continuous flows of seawater along the oceanic crust, where moving continents sculpt the sea floor and form volcanoes, transferring both energy and raw materials to the ocean.

In January 2014 Foustoukos, along with microbiologist and Carnegie postdoctoral fellow Ileana Peréz-Rodríguez and undergraduate student Matt Rawls of George Mason University, collected microorganisms from the volcanoes of the Pacific Ocean and cultured them onboard the oceanographic research vessel *Atlantis*.

The Carnegie team designed experiments that simulate the extreme conditions of the deep oceans. Using the high-pressure bioreactor, microorganisms were grown at pressures of nearly 400 times normal atmospheric pressure and temperatures as high as 149 degrees Fahrenheit (65 degrees Celsius). This is the first time that microorganisms from deep-sea submarine volcanoes have been sampled, transferred, and cultured under such high-pressure and high-temperature conditions.

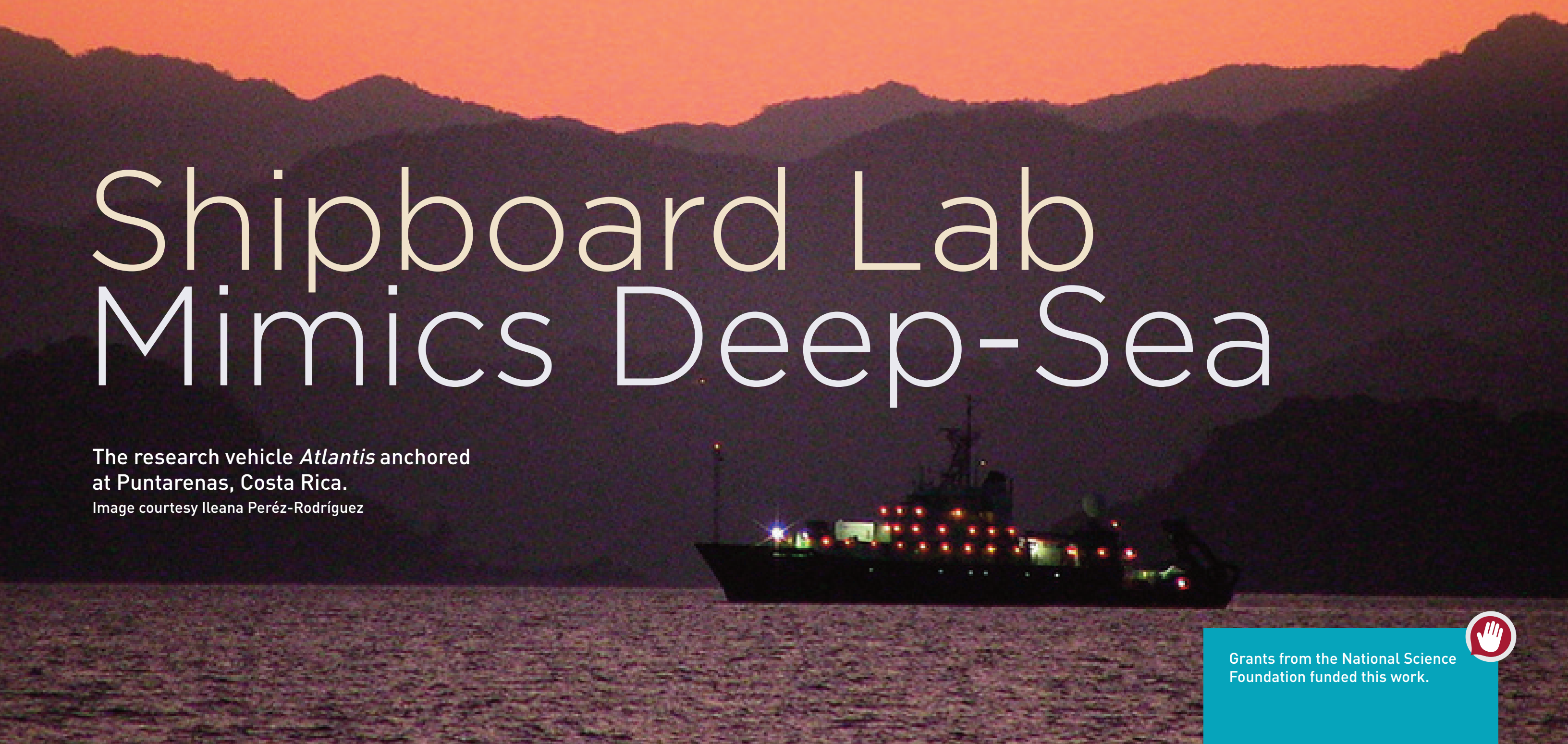
These technological advances, which allow microbial culturing at conditions resembling those of extreme environments, shed light on the mechanisms that living organisms use to thrive and function in less-extreme terrestrial habitats.

Through a strongly interdisciplinary and multi-institutional research program, Foustoukos' future work aims to study the emergence and evolution of microbial metabolism on early Earth. In addition, future industrial applications for his research could target the degradation of petroleum by deep-dwelling bacteria, as well as the possibility of synthesizing biofuels under the conditions that mimic Earth's undersea oil reservoirs. □



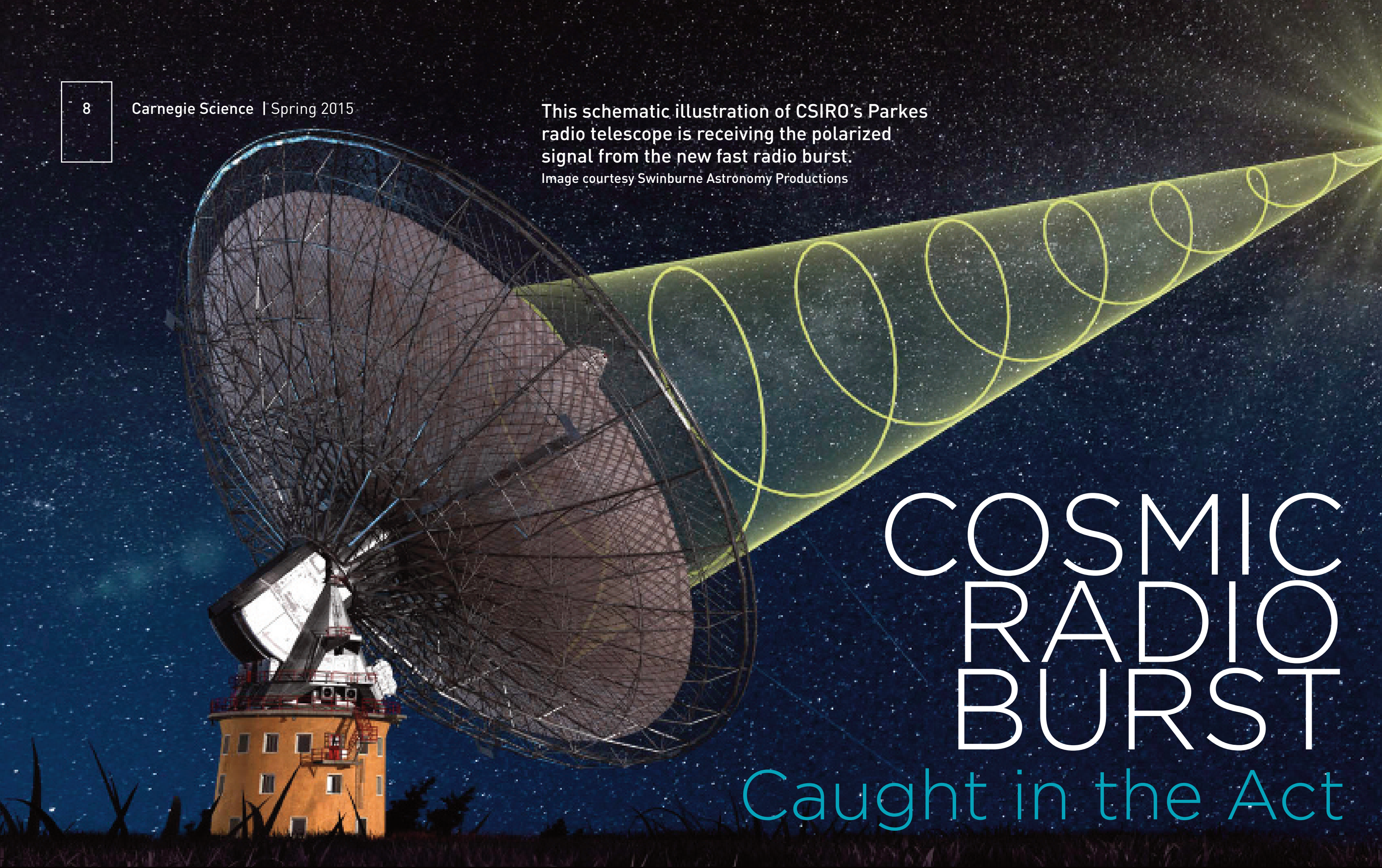
(Top) The unmanned submersible *Jason* is deployed from the research vehicle *Atlantis.*
Image courtesy Dionysis Foustoukos

(Bottom) Ileana Peréz-Rodríguez and Dionysis Foustoukos repair the onboard spectrophotometer.
Image courtesy Matt Rawls



The research vehicle *Atlantis* anchored at Puntarenas, Costa Rica.
Image courtesy Ileana Peréz-Rodríguez

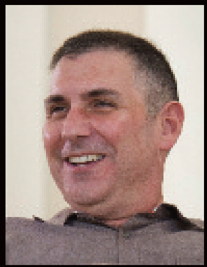
Grants from the National Science Foundation funded this work.



This schematic illustration of CSIRO's Parkes radio telescope is receiving the polarized signal from the new fast radio burst.
Image courtesy Swinburne Astronomy Productions

COSMIC RADIO BURST
Caught in the Act

This is an artist's conception of a magnetar, neutron stars with extremely strong magnetic fields.
Image courtesy the European Southern Observatory, L. Calçada



John Mulchaey

Mansi Kasliwal

Images courtesy Tim Neighbors

Fast radio bursts are quick, bright flashes of radio waves from an unknown source in space. They are a mysterious phenomenon that last only a few milliseconds, and until now they have not been observed in real time. An international team of astronomers, including Carnegie's John Mulchaey, Mansi Kasliwal, and Yue Shen, observed a fast radio burst happening live for the first time.

There is a great deal of scientific interest in fast radio bursts, particularly in uncovering their origin. Only seven fast radio bursts have previously been discovered—the first in 2007; all were found retroactively by combing through data from the Parkes radio telescope in eastern Australia and the Arecibo Observatory in Puerto Rico.

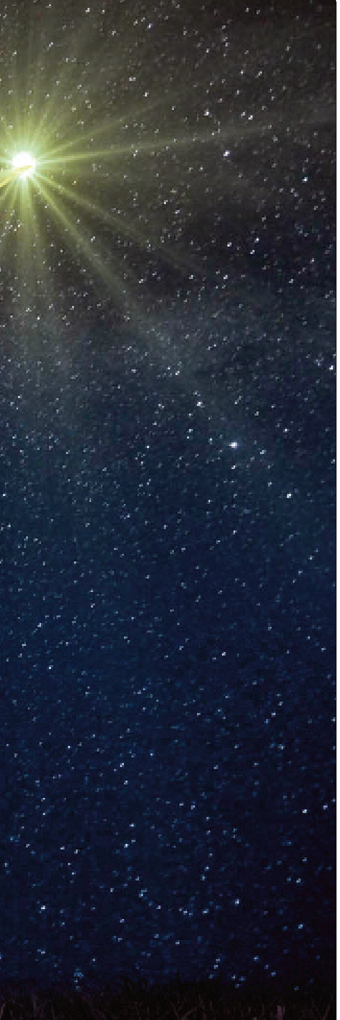
To observe the fast radio burst in real time, the team mobilized 12 telescopes around the world and in space, including Carnegie's Magellan and Swope telescopes. Each telescope followed up on the original burst observation at different wavelengths.

Measurements of the interaction between previously detected fast radio burst's flashes and the free electrons their signals encountered in space as they traveled to reach us had previously indicated that the bursts likely originated far outside of our galaxy. But the idea was controversial.

The team's data indicate that the burst originated up to 5.5 billion light-years away. This means that the sources of these bursts are extremely bright; they can perhaps be used as a cosmological tool for measuring and understanding our universe once we come to understand them better.

The observations allowed the team to rule out some of the previously proposed sources for the bursts, including nearby supernovae and long gamma-ray bursts. But short gamma-ray bursts are still a possibility. Gamma-ray bursts are high-energy explosions that form some of the brightest celestial events. Long bursts can signify energy released during a supernova and are followed by an afterglow, which emits lower wavelength radiation than the original explosion. Another possibility still on the table is distant magnetic neutron stars called magnetars.

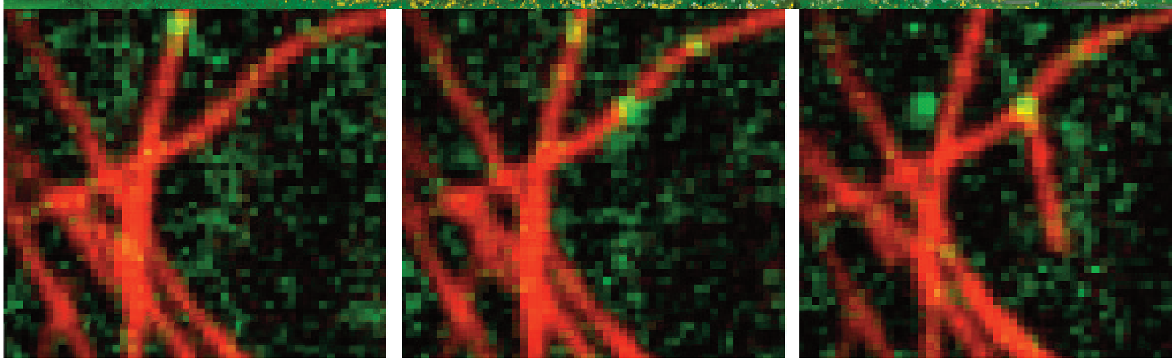
An interesting piece of information the team was able to gather about the burst is its polarization. The orientation of the radio waves indicates that the burst likely originated near or passed through a magnetic field, information that can help narrow down potential sources going forward. □



Monthly Notices of the Royal Astronomical Society published their work.

The Parkes radio telescope and the Australia Telescope Compact Array are part of the Australia Telescope National Facility, which is funded by the Commonwealth of Australia for operation as a National Facility and managed by CSIRO. The Australian Research Council Centre of Excellence for All-Sky Astrophysics (CAASTRO) conducted parts of this research. The Giant Metrewave Radio Telescope (GMRT) is run by the National Centre for Radio Astrophysics of the Tata Institute of Fundamental Research. Research with the Australian National University's SkyMapper telescope is supported in part through an Australian Research Council Discovery Grant. Part of the funding for the Gamma-Ray Burst Optical/Near-Infrared Detector (GROND) was granted from a Leibniz Prize. The Dark Cosmology Centre is supported by the Danish National Research Foundation. Other support came from a Curtin Research Fellowship; Exploring the X-ray Transient and variable Sky (EXTraS), funded from the European Union's Seventh Framework Programme for research, technological development, and demonstration; Hubble Fellowships; a Carnegie-Princeton Fellowship; the Arye Dissentshik Career Development Chair; the Willner Family Leadership Institute; Ilan Gluzman (Secaucus, N.J.) the Israeli Ministry of Science; Israel Science Foundation; NASA's Minerva project; Weizmann UK; and the Israeli Centers for Research Excellence Program (I-CORE).

Cell Architecture:
Function Follows Form



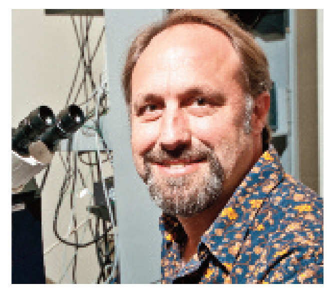
Plant cells contain a dynamic cytoskeleton, which is responsible for directing cell growth, development, movement, and division. Over time, changes in the cytoskeleton form the shape and behavior of cells and, ultimately, the structure and function of the organism as a whole. Research led by Carnegie's David Ehrhardt homes in on how one particular organizational protein influences cytoskeletal and cellular structure in plants, a finding that may have implications for animals.

A cell's cytoskeleton features microtubules, which consist of a protein called tubulin assembled into long tubular polymers. Tubulin and tubulin-like proteins are old evolutionarily, shared by different lifeforms including some bacteria, higher plants, fungi, and animals, and they play critical roles in how their cells grow and divide. The work from Ehrhardt's team—which includes Carnegie's Ankit Walia (the lead author), Masayoshi Nakamura, and Dorianne Moss—focuses on microtubule involvement in the growth of plant cells after cell division; they discovered a new role for a protein crucial for cell division in mammals.

The role of microtubules in animal cell division is well understood. Cells divide using a process called mitosis, during which duplicate copies of the cell's DNA-containing chromosomes are separated into two distinct cells. A microtubule scaffold is crucial for pulling the duplicated halves of the chromosome apart and directing them to each of the new daughter cells.

There is a major difference between microtubule-assisted cell division in plants and animals. In animal (and yeast) cells, the microtubules that separate chromosomes during cell division are usually organized around a central structure. In plant cells, the arrays of microtubules lack these central hubs.

How microtubules are properly positioned to perform their function without the aid of a central organizing structure is poorly understood and is the focus of the team's research. What they found is that a protein called GCP-WD, which plays a key role in the central microtubule organizational structure in mammals, is also crucial in plants. GCP-WD is key for positioning the formation of individual microtubules in plant cells, and it is important for the organization and function of plant cell skeletons overall, beyond just the division process. □



David Ehrhardt

Image courtesy Robin Kempster

(Top) Microtubules, which help shape a cell's architecture as well as the structure and function of the organism as a whole, are composed of the protein tubulin, which is found in higher plants, fungi, and animals.

Image by George Hodan courtesy publicdomainpictures.net

(Bottom) Microtubules are labeled in red; the green dots are GCP-WD particles. The microtubule initiated from a location marked by GCP-WD.

Image courtesy Ankit Walia

Current Biology published this work in October.

Endowment funds of the Carnegie Institution for Science and a Human Frontier Science Program fellowship for a post-doctoral fellow supported this work.

CARNEGIE STANDS OUT!

WELCOME

MARGARET MOERCHEN
Joins Carnegie as Science Deputy

Astronomer and associate editor of *Science* magazine, Margaret Moerchen, was appointed Science Deputy to the President. She will work on new programs for Carnegie Science, strategic planning, scientific reviews of staff and departments, organizing and monitoring ongoing scientific collaborations and teams, and partnerships with other organizations. She will also serve as liaison to all our scientists, increasing contact time between P Street staff and department scientists.

At *Science* since 2014, Margaret handled all astronomy and planetary science manuscripts. Her interactions with other editors at the journal enhanced her knowledge of other physical sciences including geophysics, climate science, chemistry, materials science, and physics—an excellent intersection for her duties as Science Deputy.

Margaret's work on instrument-building teams at the world's largest telescopes has required strong leadership, active communication, and collaboration with diverse scientists and engineers. She recently served as a support astronomer at the Very Large Telescope in Chile, where she led the nightly operation plan of one of its 8-meter telescopes. There, she coordinated an international team and engaged on-call engineers in frequent problem-solving sessions. In a concurrent role as a scientific liaison, she was often called on to explain the mission to visiting officials and represented the observatory in a popular outreach event, a live webcast for "Around the World in 80 Telescopes," for the International Year of Astronomy in 2009.

MARNIE HALPERN
Named AAAS Fellow

Biologist Marnie Halpern of Embryology was named a fellow of the American Association for the Advancement of Science (AAAS) for her "fundamental contributions to developmental biology, particularly using novel genetic approaches to study patterning of the nervous system."

Using the tiny zebrafish, *Danio rerio*, Halpern explores how regional specializations occur within the neural tube, the embryonic tissue that develops into the brain and spinal cord.

ERIK HAURI
Elected Fellow of the Geochemical Society and European Association of Geochemistry

Erik Hauri of Terrestrial Magnetism studies how planetary processes affect the chemistry of the Earth, Moon and other objects. He was made a fellow of both the Geochemical Society and the European Association of Geochemistry in February.

Hauri studies isotopic and chemical evolution of the Earth's deep interior by modeling the flow and melting in deep Earth mantle plumes. He uses high-pressure experimental petrology and secondary ion mass spectrometry.

ANAT SHAHAR
Awarded the Clarke Award of the Geochemical Society

Anat Shahar of the Geophysical Laboratory was awarded the Geochemical Society's F. W. Clarke Award. This award is given to an early-career scientist for "a single outstanding contribution to geochemistry or cosmochemistry, published either as a single paper or a series of papers on a single topic."

Shahar blends high-pressure techniques with isotope geochemistry to study interior materials under the extreme conditions that exist there. Her goal is to understand how the Earth and other Solar System bodies formed, focusing on the composition and layering history of the Earth's core and mantle.

SEAN SOLOMON (Top, on left)
Awarded National Medal of Science

On November 20, former Terrestrial Magnetism director Sean Solomon received the National Medal of Science from President Obama at a White House ceremony "for creative approaches and outstanding contributions to understanding the internal structure and evolution of the Earth, the Moon, and other terrestrial planets and for his leadership and inspiration of new generations of scientists." It is the nation's highest scientific honor.

Solomon's career has been characterized by an uncommon combination of science and leadership. He established important new paradigms in the Earth and planetary sciences, while simultaneously leading the field of geophysics.

TIMIA McCLAIN
Joins Carnegie as Scientific Programs & Outreach Manager

Timia McClain, in collaboration with other Carnegie scientists, will create and execute scientific conferences, lecture series, exhibits, and online presentations for scientific advancement and educating the public about science.

McClain recently completed her Ph. D. at UC-San Diego (UCSD) in chemistry, conducting her thesis work on reactive gases in the marine boundary layer of the atmosphere. She was instrumental in developing a novel spectrometer used in the field to sample trace gases in near-real time, looking at the sources and fate of the gases and the implications for public health. During her graduate career she was heavily involved in external affairs, science education and outreach, and science policy.

McClain served as vice president of external affairs and the cultural events coordinator in the UCSD Graduate Student Association, valuable experience for understanding how science and higher education intersect with policy. She served as an NSF graduate STEM fellow, developing lesson plans and teaching chemistry to high school students. Those experiences and her outreach activities added to her strong communication skills for translating science, across a broad range of topics, to lay audiences.

Richard Meserve (right) enjoys humorous remarks with the evening's speaker, friend, and former Secretary of the Smithsonian Wayne Clough.

Trustees Bid Farewell to Richard Meserve

Carnegie president since 2003, Richard Meserve stepped down from the position in September. The trustees bade him farewell with a recognition celebration on November 20, which happened to coincide with Meserve's birthday. His family, friends, and many, many colleagues attended the festivities. Magician Brian Curry set the tone by entertaining guests with sleights of hand during the cocktail hour and, later, at the podium with Meserve assisting. After remarks by current Carnegie president Matthew Scott, board cochairs Steve Fodor and Suzanne Nora Johnson presided over the program. They introduced a video tribute by Secretary of Energy Ernest Moniz, Meserve's longtime friend. During dinner, trustees Rush Holt, Bruce Ferguson, and Mike Gellert gave remarks about Meserve's legacy, punctuated with humorous anecdotes. The cochairs then introduced a birthday cake and gift representing each area of Carnegie science, contributed by the department directors. Former Secretary of the Smithsonian and longtime friend Wayne Clough was the evening's speaker. After the talk, the board cochairs announced the creation of the Meserve Public Service Award in his honor. The award will be presented annually to recognize an individual who has made exceptional contributions to science through advancing public understanding of science and its role in the betterment of humankind. The evening concluded with Meserve's remarks and heartfelt thanks. □

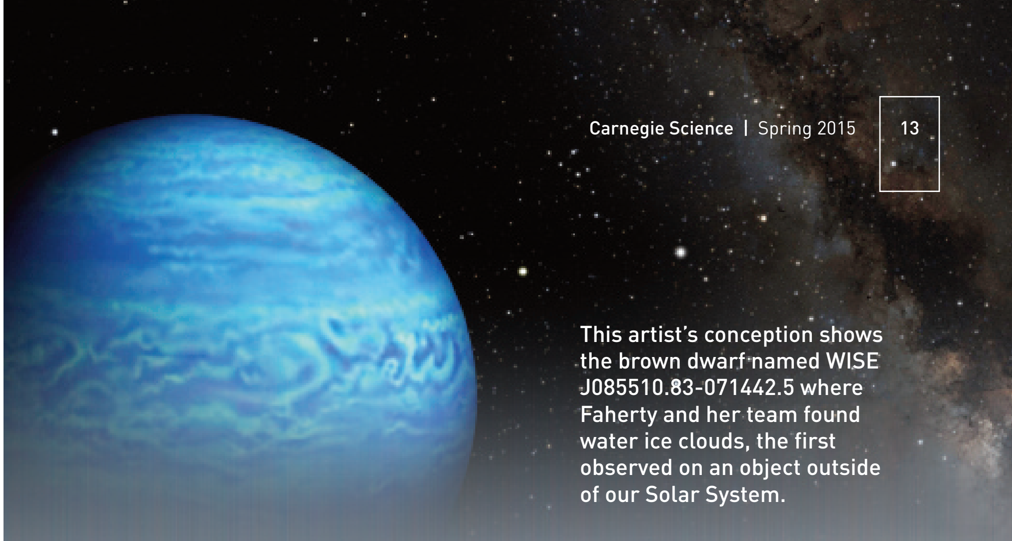
Right, top to bottom:
Meserve granddaughters are entertained by sleights of hand performed by magician Brian Curry (right) during the cocktail hour.

Carnegie Board of Trustees cochairs Steve Fodor and Suzanne Nora Johnson presided over the evening's program.

Secretary of Energy and longtime friend Ernest Moniz paid tribute to Meserve via video.

Carnegie board cochairs introduce the birthday cake; Meserve's granddaughters help blow out the candles.

Images courtesy David Keith



This artist's conception shows the brown dwarf named WISE J085510.83-071442.5 where Faherty and her team found water ice clouds, the first observed on an object outside of our Solar System.

Water Ice Clouds Found Outside Solar System!

A team of scientists led by Carnegie's Jacqueline Faherty has discovered the first evidence of water ice clouds on an object outside of our own Solar System. Water ice clouds exist on our own gas giant planets—Jupiter, Saturn, Uranus, and Neptune—but have not been seen outside of the planets orbiting our Sun until now.

At the Las Campanas Observatory in Chile, Faherty, along with a team including Carnegie's Andrew Monson, used the FourStar near-infrared camera to detect the coldest brown dwarf ever characterized. Their findings are the result of combining 151 images taken over three nights. NASA's Wide-Field Infrared Survey Explorer mission first saw the object, named WISE J085510.83-071442.5, or W0855; its discovery was published earlier this year. But it was not known if W0855 could be detected by Earth-based facilities until now.

Brown dwarfs aren't quite very small stars, but they aren't quite giant planets either. They are too small to sustain the hydrogen fusion process that fuels stars. Their temperatures can range from nearly as hot as a star to as cool as a planet, and their masses also range between star-like and giant planet-like. They are of particular interest to scientists because they offer clues to star-formation processes. They also overlap with the temperatures of planets, but they are much easier to study since they are commonly found in isolation.

W0855 is the fourth-closest system to our own Sun, practically a next-door neighbor in astronomical distances. A comparison of the team's near-infrared images of W0855 with models for predicting the atmospheric content of brown dwarfs showed evidence of frozen clouds of sulfide and water. □

Jacqueline Faherty

The Astrophysical Journal Letters published their findings.

The Australian Research Council supported this work. The team made use of data from the NASA WISE mission, a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory (JPL) and Caltech, funded by NASA. They also made use of the NASA/IPAC Infrared Science Archive, which is operated by JPL and Caltech, under contract with NASA.

How Baby Cells
Learn to Communicate

Scientific dogma is often overturned. Most developmental biologists, for instance, have assumed that young cells, recently born from stem cells and known as progenitors, are already competent at intercommunication with other cells. Not so.

New research from Carnegie's Allan Spradling and postdoctoral fellow Ming-Chia Lee shows that infant cells have to go through a developmental process involving specific genes before they can take part in the group interactions that underlie normal cellular development and smooth functioning. The existence of a childhood state where cells cannot communicate fully has potentially important implications for our understanding of how gene activity changes during normal development and in cancerous cells. *Genes and Development* published their work.

The way that the molecules that package a cell's chromosomes are organized to control gene activity is known as the cell's "epigenetic state." The epigenetic state is fundamental to understanding Spradling and Lee's findings. To developmental biologists, changes in this epigenetic state ultimately explain how the cell's properties are altered during tissue maturation.

"In short, acquired epigenetic changes in a developing cell are reminiscent of the learned changes the brain undergoes during childhood," Spradling explained. "Just as it remains difficult to map exactly what happens in a child's brain as it learns, it is still very difficult to accurately measure epigenetic changes during cellular development. Not enough cells can usually be obtained that are at precisely the same stage for scientists to map specific molecules at specific chromosomal locations."

Lee and Spradling took advantage of the unsurpassed genetic tools available in the fruit fly to overcome these obstacles and provide new insight into the epigenetics of cellular development.

Using a variety of tools and techniques, they focused on cells in the fruit fly ovary and were able identify a gene called *Lsd1* that is needed for ovarian follicle progenitor cells to mature at their normal rate. The researchers found that the amount of the protein that is encoded by this gene, which is present in follicle progenitors, decreases as the cells approach differentiation. What's more, changing the levels of Lsd1 protein could shift the onset of differentiation. They deduced that differentiation begins when Lsd1 levels fall below a critical threshold and that this likely corresponds to when genes can be stably expressed.

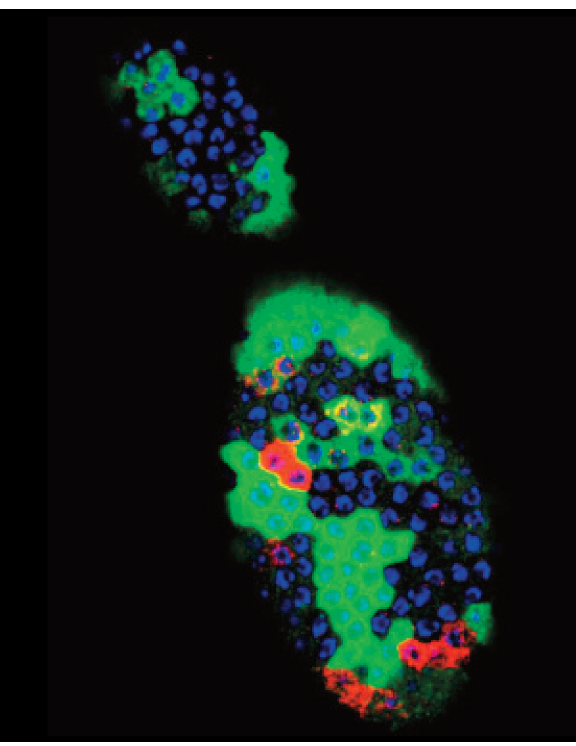
"The timing of differentiation is very important for normal development," Lee said. "Differentiation onset determines how many times progenitors divide, and even small perturbations in Lsd1 levels changed the number of follicle cells that were ultimately produced, which reduced ovarian function."

Previously, it was thought that the follicle cell progenitors started to differentiate based on an external signal they received from another kind of ovarian cell known as germ cells. Lee and Spradling found that while this germ cell signal was essential, it was already being regularly sent even before the progenitors responded. Instead, it was the Lsd1-mediated change in their epigenetic state that timed when progenitor cells started to respond to the signal and began differentiating. Once they become competent, however, differentiating follicle cells communicate extensively with their neighbors, and continue to do so throughout their lives.

As is frequently the case, the molecules and mechanisms studied here are found in most multicellular animals, so the researchers' conclusions are likely to apply broadly throughout the animal kingdom, including in humans.

In addition to the importance of this research for understanding how animal chromosomes change during normal development, it may also help clarify alterations in the epigenetic state that take place in some cancers. A minority of cells in such cancers begins to express high levels of Lsd1 and to behave like undifferentiated progenitors.

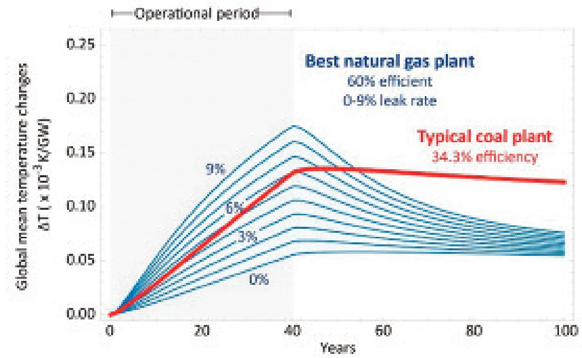
"Studying fruit fly follicle cell differentiation can teach us at a deeper level what Lsd1 is doing in both normal and cancerous progenitors," Lee added. □

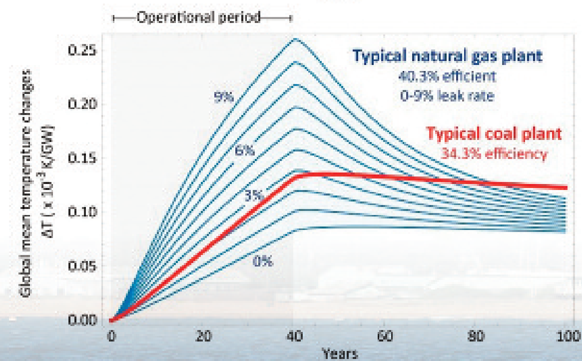


(Left) This micrograph shows fruit fly ovarian follicle progenitor cells. Different colors mark a specific kind of activity (red), specific gene expression (green), and nuclear DNA (blue).
Image courtesy Ming-Chia Lee

(Above) Allan Spradling has been the department director since 1994.

The Howard Hughes Medical Institute funded this work in part.

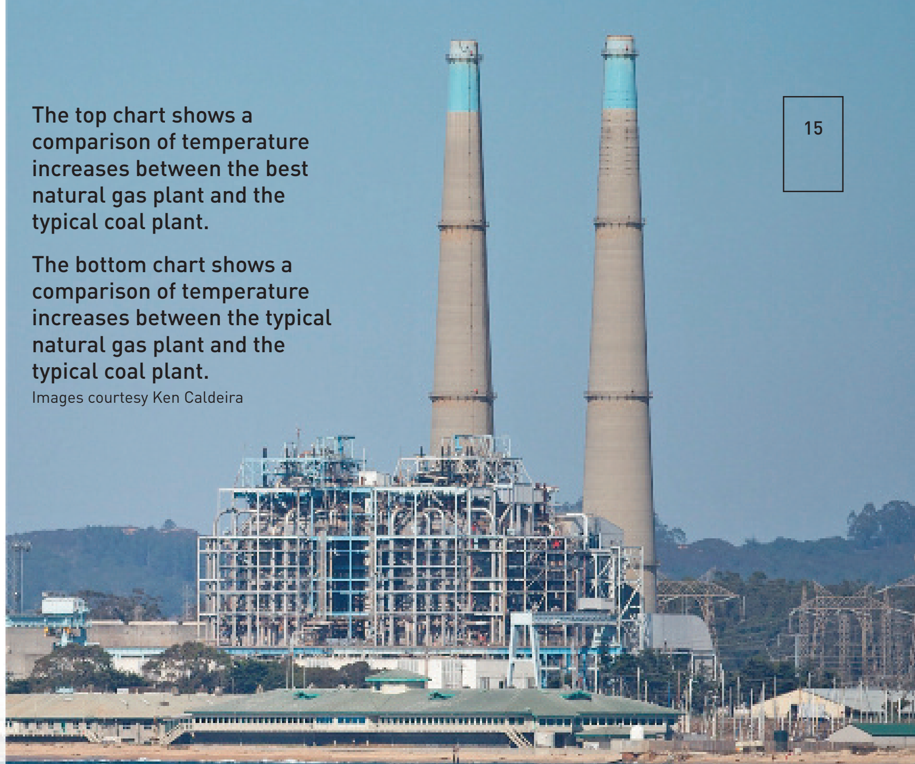




The top chart shows a comparison of temperature increases between the best natural gas plant and the typical coal plant.

The bottom chart shows a comparison of temperature increases between the typical natural gas plant and the typical coal plant.

Images courtesy Ken Caldeira



(Above) This natural gas plant was converted from coal in Moss Landing, California.

Image courtesy Carnegie President Matthew Scott

(Below, left) Ken Caldeira

Image courtesy Robin Kempster

GAS OR COAL: Which Has a Hotter Future?

There is an ongoing debate among people concerned with power plants and the future of energy policy and greenhouse gas emissions. Does it makes sense to replace old coal-fired power plants with new natural gas power plants today, as a bridge to a longer-term transition toward near zero-emission technologies such as solar, wind, or nuclear power? A key issue in considering the decision has been the potential climate effects of natural gas versus coal.

New research from Carnegie's Ken Caldeira and Xiaochun Zhang and Intellectual Ventures' Nathan Myhrvold compared the temperature increases caused by different kinds of coal and natural gas power plants. They found that, unless the methane leakage rates of natural gas plants are very low and the plants are very efficient, replacing old coal-fired power plants with new natural gas plants could cause climate damage to increase over the next decades.

The research team aimed to identify the key factors that are responsible for most of the difference in greenhouse gas emissions between individual gas and coal plants. The key factors, they found, are power plant efficiency and, in the case of natural gas plants, methane leakage during the supply process. They used these factors to derive a simple model for resulting temperature change caused by the carbon dioxide and methane released by a particular plant.

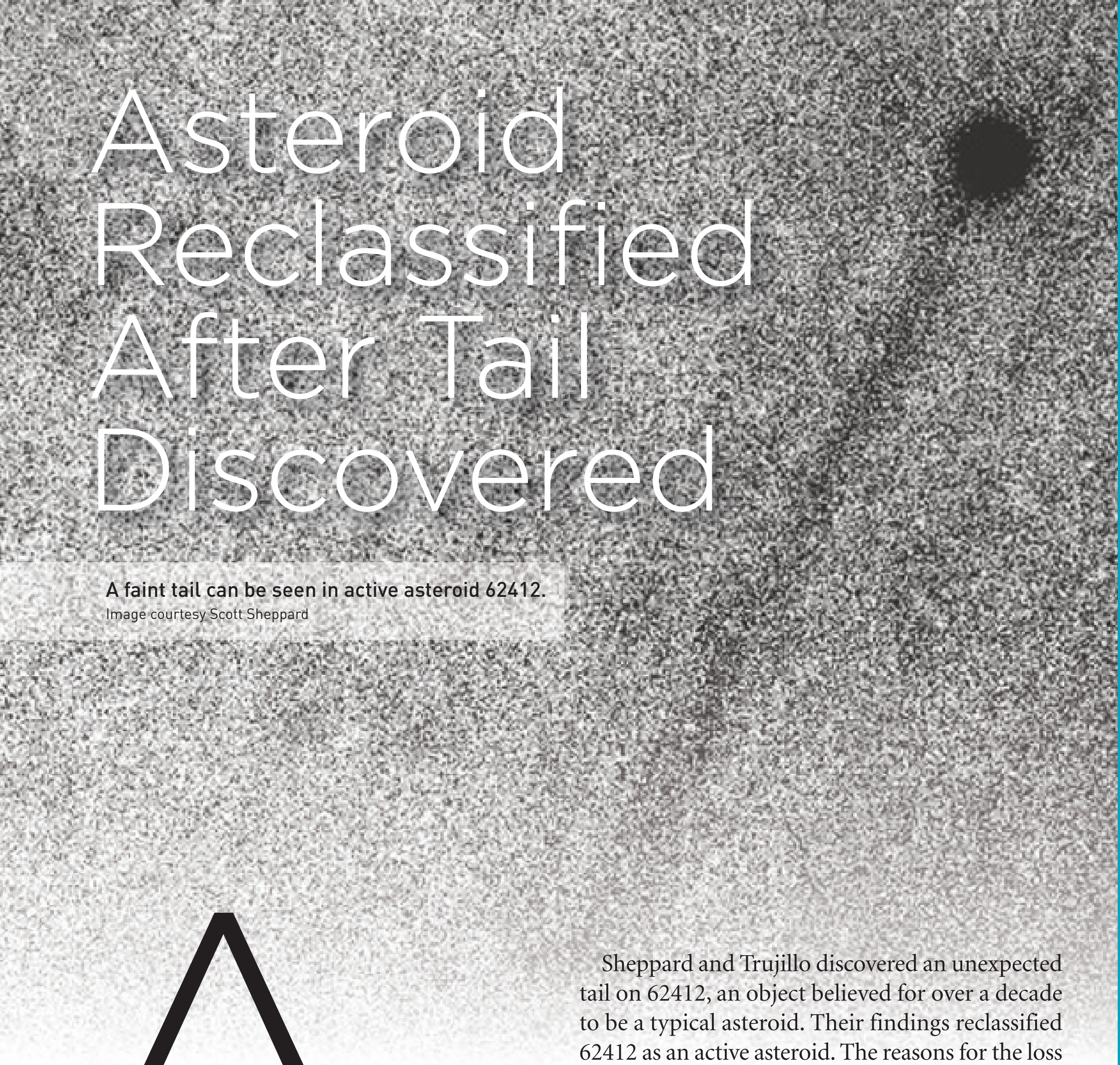
They found that because natural gas plants are overall more efficient than coal plants, producing more energy per unit of carbon, they could cause less warming in the long term. However, it all depends on the amount of methane leakage that occurs. Natural gas plants that leak a substantial amount of methane during their supply process can produce more warming than comparable coal plants.

If faced with the choice of shutting down either a typical coal plant or a typical gas plant, and methane leakage from the natural gas plant is below about 2 percent of total fuel, there would be a short-term climate benefit to shutting down the coal plant instead of the natural gas plant, the team found. But if methane leakage were greater than 2 percent, there would be less warming in the near term if the natural gas plant were shut down instead of the coal plant.

Regardless, the team emphasized that meeting upcoming greenhouse gas emission targets will require deeper emissions cuts than just building natural gas plants with low methane leakage. If natural gas is to be a part of a future near-zero emission energy economy, methods for capturing and storing carbon from gas-fired power plants will likely be necessary. □

Environmental Research Letters published their work in December.

Asteroid Reclassified After Tail Discovered



A faint tail can be seen in active asteroid 62412.
Image courtesy Scott Sheppard

A two-person team of Carnegie's Scott Sheppard and Chadwick Trujillo of the Gemini Observatory has discovered a new active asteroid called 62412 in the Solar System's main asteroid belt between Mars and Jupiter.

Active asteroids are a newly recognized phenomenon. 62412 is only the 13th known active asteroid in the main asteroid belt, and it is the first comet-like object seen in the Hygiea family of asteroids. Based on their discovery, Sheppard and Trujillo estimate that there are likely about 100 active asteroids in the main asteroid belt.

In the past asteroids were thought to be mostly unchanging objects, but an improved ability to observe them has allowed scientists to discover tails and comas, the thin envelope of an atmosphere that surrounds a comet's nucleus, on them. Like other asteroids, active asteroids have stable orbits between Mars and Jupiter. However, unlike other asteroids, active asteroids sometimes have the appearance of comets, when dust or gas is ejected from their surfaces to create a sporadic tail effect.

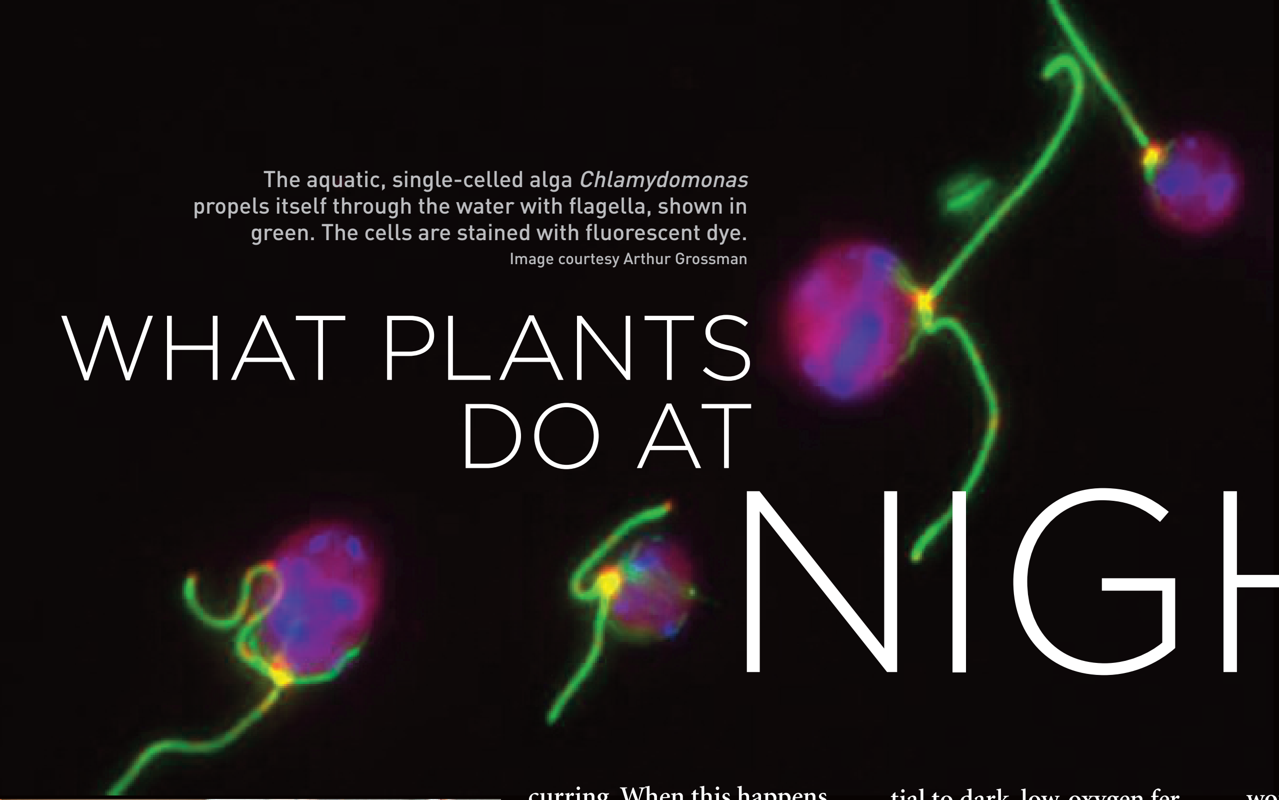
Sheppard and Trujillo discovered an unexpected tail on 62412, an object believed for over a decade to be a typical asteroid. Their findings reclassified 62412 as an active asteroid. The reasons for the loss of material and subsequent tail in active asteroids are unknown, although there are several theories such as recent impacts or sublimation from solid to gas of exposed ices. Sheppard and Trujillo were able to make their discovery because of the depth of their survey.

Scott Sheppard
Image courtesy Scott Sheppard

Discoveries such as this one can help researchers determine the processes that cause some asteroids to become active. They found that 62412 has a very fast rotation that likely shifts material around its surface. The tail may be created by material ejected off the fast rotating nucleus or by ice within the asteroid subliming into water vapor after being freshly exposed on the surface. They also found 62412's density is typical of primitive asteroids and not consistent with the much lower-density comets. Further monitoring of this unusual object will help confirm the activity's source.

Sheppard presented these findings at the American Astronomical Society's Division of Planetary Sciences meeting in November. □

A NASA Planetary Astronomy grant funded this research. Chadwick Trujillo is supported in part by the Gemini Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., on behalf of the international Gemini partnership of Argentina, Australia, Brazil, Canada, Chile, the United Kingdom (U.K.), and the U.S. This research used the facilities of the Canadian Astronomy Data Centre operated by the National Research Council of Canada with the support of the Canadian Space Agency. This paper includes data gathered with the 6.5-meter Magellan telescopes located at Las Campanas Observatory, Chile. This project used data obtained with the Dark Energy Camera (DECam), which was constructed by the Dark Energy Survey (DES) collaborating institutions: Argonne National Laboratory; University of California, Santa Cruz; University of Cambridge; Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas, Madrid; University of Chicago; University College London; DES-Brazil consortium; University of Edinburgh; ETH Zurich; University of Illinois, Urbana-Champaign; Institut de Ciencies de l'Espai; Institut de Fisica d'Altes Energies; Lawrence Berkeley National Lab; Ludwig-Maximilians Universitat; University of Michigan; National Optical Astronomy Observatory; University of Nottingham; Ohio State University; University of Pennsylvania; University of Portsmouth; SLAC National Accelerator Laboratory; Stanford University; University of Sussex; and Texas A&M University. The U.S. Department of Energy, National Science Foundation (NSF), Spain's Ministry of Education and Science, the U.K.'s Science and Technology Facilities Council and the Higher Education Funding Council, National Center for Supercomputing Applications, Kavli Institute for Cosmological Physics, Financiadora de Estudos e Projetos, Fundacao Carlos Chagas Filho de Amparo a Pesquisa, Conselho Nacional de Desenvolvimento Cientifico e Tecnologico and the Ministerio da Ciencia e Tecnologia (Brazil), the German Research Foundation-sponsored cluster of excellence "Origin and Structure of the Universe," and the DES-collaborating institutions provided funding for DES, including DECam. Observations were partly obtained at Cerro Tololo Inter-American Observatory and the National Optical Astronomy Observatory, which are operated by the Association of Universities for Research in Astronomy under contract with NSF.



The aquatic, single-celled alga *Chlamydomonas* propels itself through the water with flagella, shown in green. The cells are stained with fluorescent dye.
Image courtesy Arthur Grossman

WHAT PLANTS DO AT NIGHT

Plants need light, right?

The process of converting light energy into food, photosynthesis, is probably the most well known aspect of plant biochemistry. Photosynthesis enables plants, algae, and certain bacteria to transform sunlight's energy into chemical energy (sugars and starches, and oils and proteins, too); it involves taking in carbon dioxide and releasing oxygen extracted from water molecules. During the night photosynthetic organisms undertake other biochemical reactions: They generate energy by breaking down the sugars and starches they stored during the day.

Cells often face low-oxygen conditions at night, when there's no photosynthesis occurring. When this happens, some organisms such as the single-cell alga *Chlamydomonas* are able to generate cellular energy from the breakdown of sugars without taking up oxygen. They do this using a variety of fermentation pathways, similar to those used by yeast to create alcohol. Many of the details regarding this low-oxygen energy creation process are poorly understood.

New work from a team including Carnegie's Wenqiang Yang and Arthur Grossman, in collaboration with Matt Posewitz at the Colorado School of Mines, homes in on the biochemical pathways underlying the special flexibility of *Chlamydomonas* in responding to zero- and low-oxygen conditions. Other Carnegie coauthors include Claudia Catalanotti, Tyler Wittkopp, Luke Mackinder, and Martin Jonikas. *The Plant Cell* published the work.

In an arduous and exacting step-by-step process, the team used a series of specially created mutants to determine the importance of two identical branches of the fermentation pathway that are located in different compartments in the cell, both believed to be essential to dark, low-oxygen fermentation in *Chlamydomonas*. The pathways are dependent on four proteins—PAT1, PAT2, ACK1, and ACK2.

ACK1 and PAT2 are located in a part of the plant cell called the chloroplast, which is the compartment where photosynthesis takes place. ACK2 and PAT1 are located in the mitochondria, the organelle in plant and animal cells where sugar breakdown takes place.

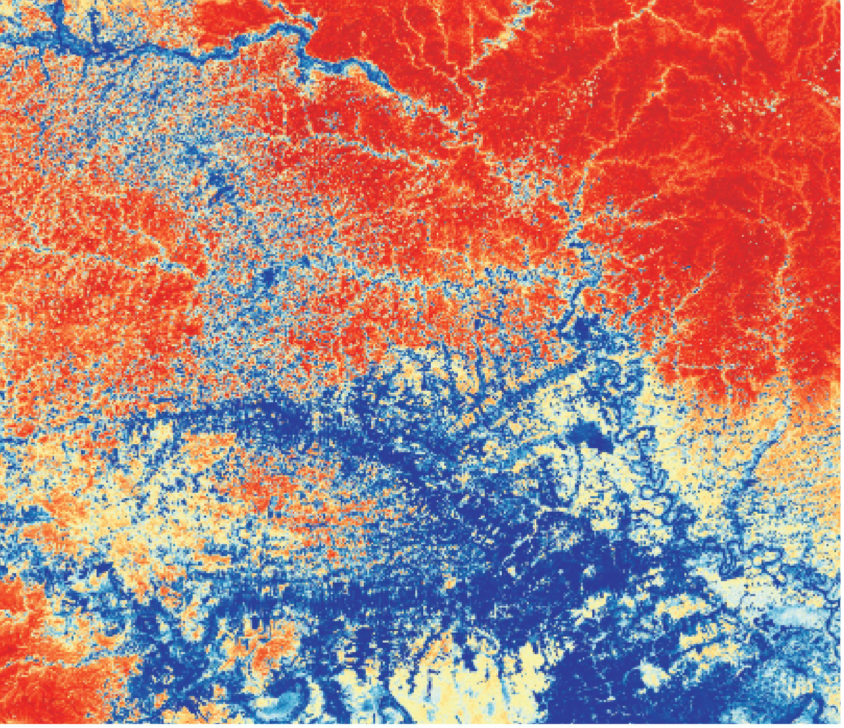
"Surprisingly, we found that the chloroplast pathway is much more critical than the mitochondrial pathway for sustaining fermentation metabolism, even though generating energy from the breaking down of sugars is generally considered a mitochondrial process," Grossman said.

What's more, they found that although the PAT- and ACK-controlled pathways are indeed crucial to generating energy under these conditions, and to producing an important metabolite called acetate, there appear to be other undiscovered biochemical pathways that are participating in this process as well, which are capable of picking up at least some of the slack in the system.

"The system needs more work, especially if we are going to understand the ways in which the day-night cycle and environmental oxygen levels impact the productivity of photosynthetic organisms on our planet," Grossman added. □

Carnegie's Arthur Grossman (above left) and Wenqian Yang (above) were among the coauthors on the study.
Images courtesy Robin Kempster

Chemical Sciences, Geosciences and Biosciences Division, Office of Science Basic Energy Sciences, U.S. Department of Energy grants; a National Science Foundation Award; and the South Carolina Experiment Station funded this work. It is designated as technical contribution of the Clemson University Experiment Station.



Breakthrough in Preserving Carbon Stocks

Carnegie's Greg Asner's team developed a new high-resolution approach that can prioritize carbon conservation efforts throughout tropical countries. The new high-resolution mapping system has revealed billions of tons of carbon in Peruvian forests that can be preserved to sequester carbon stocks in the fight against climate change. Tropical forests convert more carbon from the atmosphere into biomass than any other terrestrial ecosystem on Earth. However, when land is disturbed by agriculture, as a wood source, or for mining, carbon is released into the atmosphere; this annually accounts for about 10 percent of the world's carbon emissions.

The team emphasized that the low cost of their project means that the same approach can be used in any country to support national and international commitments to reduce and offset carbon emissions. *Proceedings of the National Academy of Sciences* published their findings.

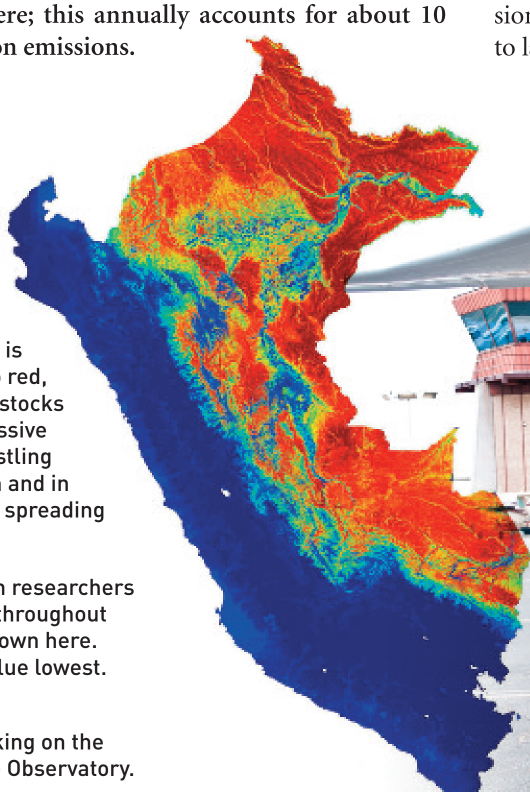
Many of the geographic details about the carbon that's stored in tropical forest ecosystems remain unknown. Details on which areas would make the best targets for protection are necessary for conservationists. This means understanding each landscape's climate, topography, geology, and hydrology.

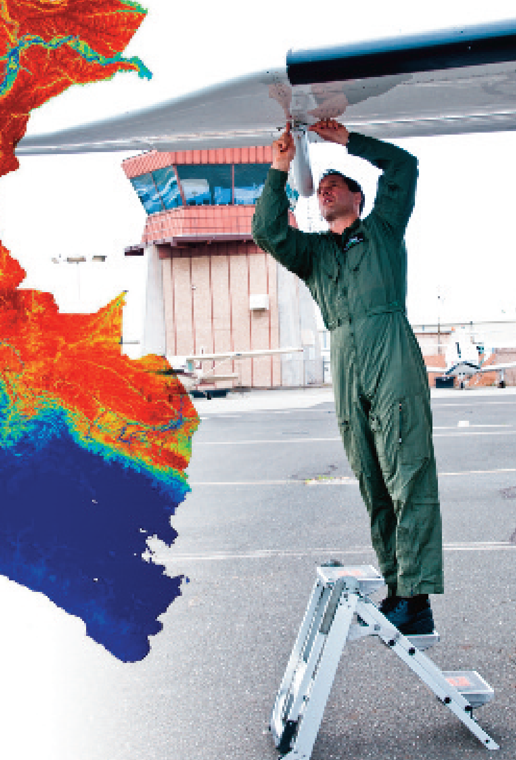
Using advanced 3-D forest mapping data provided by the Carnegie Airborne Observatory (CAO), integrated with satellite imaging data, the team was able to create a map of carbon density throughout the 317 million-acre (128 million-hectare) country of Peru, at a resolution of 2.5 acres—one hectare.

"We found that nearly a billion metric tons of aboveground carbon stocks in Peru are at imminent risk for emission into the atmosphere due to land uses such as fossil fuel exploration, cattle ranching, oil palm plantations, and gold mining," Asner said. "The good news is that our high-resolution mapping was able to identify three strategies for offsetting these upcoming emissions."

The team determined that there are opportunities to establish additional protected areas in some lowland Amazonian regions of Peru, where they found very high carbon densities, as well as in the so-called submontane region, which exists between the lowland Amazonian and the Andean highlands. Together the lowland Amazonian and submontane forests offer about 74 million acres (30 million hectares) for potential, new protected forests, which may be able to store close to 3 billion metric tons of carbon.

"Research is necessary to determine the exact state of our forests," stated Manuel Pulgar-

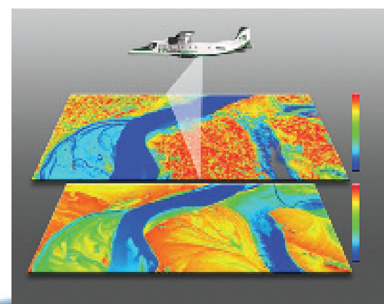




(Above) An image from the Peru-wide, high-resolution carbon map shows the effects of deforestation on a more local level. The colors range from blue, where there is no more carbon remaining, to red, a region of ultra-high carbon stocks in the surrounding forest. Massive losses are apparent in the bustling city of Pucallpa on the bottom and in the thousands of small farms spreading into the forest.

(Right) Carnegie and Peruvian researchers quantified the carbon stocks throughout the entire country of Peru, shown here. Red is highest carbon, dark blue lowest.
Images courtesy Greg Asner

(Far right) Greg Asner is working on the fixed-wing Carnegie Airborne Observatory.
Image courtesy Robin Kempster



The team's approach combines satellite and geographic information data, with Light Detection and Ranging (LiDAR) and field plot calibrations. The information is modeled to develop maps of aboveground carbon density. This schematic shows LiDAR data being collected by the Carnegie Airborne Observatory. The system sends out laser pulses. The laser light interacts with the foliage below and then returns to an onboard sensor. The returning light allows the vertical distribution of the canopy to be measured.
Image courtesy Greg Asner

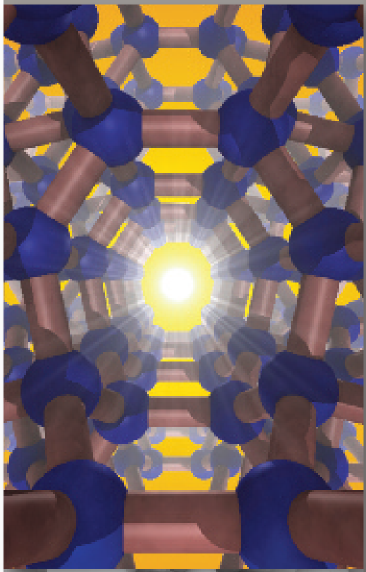
Vidal, Peru's Minister of Environment. "For that, the Carnegie Institution, with the support of the Peruvian Environment Ministry, has developed the first high-resolution map of Peru's carbon stocks. This new map provides the evidence needed to start negotiating in the carbon market at a bigger scale. Our government is also studying carbon stocks in the soil and is doing a forest inventory, and we have a forest investment program. These initiatives will better prepare us to face changes in land use."

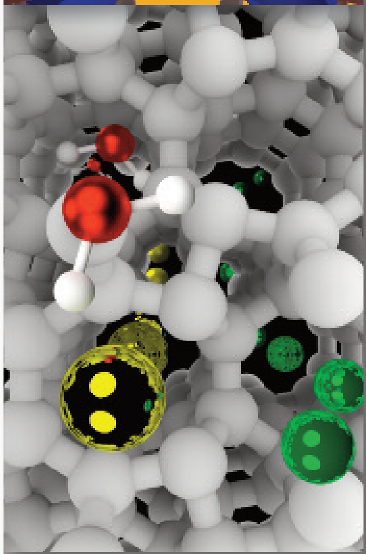
The team also asserted that there are further opportunities for offsetting future emissions by improving enforcement in areas that are already designated for carbon stock protection. According to their research, the majority of already protected carbon stocks exist only in 10 parks and reserves, and just four of these are fully enforced.

"Transitioning partially protected preserves to fully protected ones would help to counterbalance a great deal of the carbon that is expected to be lost due to land use in the near future," Asner said.

Other suggested measures include reducing forest disturbances that occur in the wake of logging and oil operations. Reduced-impact logging and restricting road access to areas where oil is being extracted could make a major difference to the net carbon emissions from the country. □

An interinstitutional working agreement between the Carnegie Department of Global Ecology and the Dirección General de Ordenamiento Territorial, Peruvian Ministry of the Environment, made this study possible. The John D. and Catherine T. MacArthur Foundation funded this study. Avatar Alliance Foundation, Grantham Foundation for the Protection of the Environment, John D. and Catherine T. MacArthur Foundation, Gordon and Betty Moore Foundation, W. M. Keck Foundation, Margaret A. Cargill Foundation, Mary Anne Nyburg Baker and Leonard Baker, Jr., and William R. Hearst III support the Carnegie Airborne Observatory.





(Top) A view through the channels of Si_{24}. This new zeolite-type allotrope of silicon has an open framework comprised of 5-, 6-, and 8-membered sp3-bonded silicon rings.

Image courtesy Timothy Strobel

Small atoms like sodium (yellow) and lithium (green), and potentially molecules like water (red), can readily diffuse through the channels of Si_{24}. Possible applications of this ability include electrical energy storage and molecular-scale filtering.

Image courtesy Duck Young Kim

(Above right) Tim Strobel

Image courtesy Natasha Metzler

Solar-Friendly Silicon Shines

Silicon is the second most abundant element in the Earth's crust. When purified, it takes on a diamond structure, which is essential to modern electronic devices. Carbon is to biology as silicon is to technology. A team of Carnegie scientists led by Timothy Strobel synthesized an entirely new form of silicon, one that promises many future applications.

Although silicon is incredibly common in today's technology, its so-called indirect band gap semiconducting properties prevent it from being considered for next-generation, high-efficiency applications such as light-emitting diodes, higher-performance transistors, and certain photovoltaic devices.

Metallic substances conduct electrical current easily, whereas insulating (non-metallic) materials conduct no current at all. Semiconducting materials exhibit mid-range electrical conductivity. When semiconducting materials are subjected to an input of a specific energy, bound electrons can move to higher-energy, conducting states. The specific energy required to make this jump to the conducting state is defined as the "band gap." While direct band gap materials can effectively absorb and emit light, indirect band gap materials, such as diamond-structured silicon, cannot. For silicon to become more attractive for use in new technology, its indirect band gap needed to be altered.

The team, which also included Carnegie's Duck Young Kim, Stevce Stefanoski, and Oleksandr Kurakevych (now at the Sorbonne), was able to synthesize a new form of silicon with a quasi-direct band gap that falls within the desired range for solar absorption, something that had never before been achieved.

The silicon they created is a so-called allotrope, which means it is a different physical form of the same element, in the same way that diamonds and graphite are both forms of carbon. Unlike the conventional diamond structure, this new silicon allotrope consists of an open framework called a zeolite-type structure, which is comprised of channels with five-, six-, and eight-membered silicon rings.

They created the allotrope using a novel high-pressure precursor process. First, a compound of silicon and sodium, Na_4Si_{24}, was formed under high-pressure conditions. Next, this compound was recovered to ambient pressure, and then heated under a vacuum to completely remove the sodium. The resulting pure silicon allotrope Si_{24} has the ideal band gap for solar energy conversion technology and can absorb, and potentially emit, light far more effectively than conventional diamond-structured silicon. □

Nature Materials published their work in November.

DARPA and the Energy Frontier Research in Extreme Environments (EFree), an Energy Frontier Research Center funded by the U.S. Department of Energy (DOE), Office of Science, supported this work. Portions of the work were performed at the High Pressure Collaborative Access Team (HPCAT) at the Advanced Photon Source, Argonne National Laboratory. HPCAT operations are supported by the DOE's National Nuclear Security Administration and Basic Energy Sciences, with partial funding by the National Science Foundation. The Advanced Photon Source is a DOE Office of Science User Facility operated for the DOE by Argonne National Laboratory. The WDC Research Fund supported, in part, X-ray diffraction studies performed at the Geophysical Laboratory. Some experiments were performed at the ID06 beamline at the European Synchrotron Radiation Facility, Grenoble, France.

The Carnegie Institution for Science is committed to the national policy of fair treatment of all employees in all aspects of employment. The institution does not discriminate against any person on the basis of race, color, religion, sex, national or ethnic origin, age, disability, veteran status, or any other basis prohibited by applicable law. This policy covers all programs, activities, and operations of the institution, including the administration of its educational programs, admission of qualified students as fellows, and employment practices and procedures.

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

Carnegie has had over 110 years of extraordinary discoveries.
To continue this tradition, Carnegie scientists need your support. To help sustain our research, contact Rick Sherman at the Office of Advancement through the Web at www.CarnegieScience.edu/donate, via phone at 202-939-1114, or write Rick Sherman, Carnegie Office of Advancement, 1530 P St., N.W., Washington, D.C. 20005-1910.

CHARITY NAVIGATOR
Four Star Charity

Carnegie Ranked Top Charity 14 Years Running

Charity Navigator, America's largest charity evaluator, ranked the Carnegie Institution for Science with its highest rating, four stars, for "sound fiscal management and commitment to accountability and transparency" for the 14th consecutive year. Only three organizations out of over 7,000* evaluated this year have received this highest rating for so many years.

Charity Navigator considers an organization's financial health plus its accountability and transparency.

Ken Berger, president and CEO of Charity Navigator, remarked in his letter to Carnegie, "Receiving four out of a possible four stars indicates that your organization adheres to good governance and other best practices that minimize the chance of unethical activities and consistently executes its mission in a fiscally responsible way. Less than 1% of the charities we rate have received at least 14 consecutive four-star evaluations, indicating that Carnegie Institution for Science outperforms most other charities in America. This 'exceptional' designation from Charity Navigator differentiates Carnegie Institution for Science from its peers and demonstrates to the public it is worthy of their trust."

Carnegie president Matthew Scott said, "This four-star rating from Charity Navigator, which our institution has earned for 14 years running, shows that Carnegie is carefully and thoughtfully shepherding our resources to effectively advance our scientific agenda. Our combination of powerful discovery science with meticulous financial management is a double distinction that would make Andrew Carnegie himself proud."

**Not all organizations have been evaluated for 14 consecutive years. For instance, this year Charity Navigator evaluated 1,000 new charities. For more about Charity Navigator see http://www.charitynavigator.org/.*