APS NEWS

A PUBLICATION OF THE AMERICAN PHYSICAL SOCIETY • WWW.APS.ORG/PUBLICATIONS/APSNEWS

May 2007
Volume 16, No. 5
www.aps.org/publications/apsnews

Highlights

Climate Change is All About Energy on page 8

Franklin's Secret Message Revealed

Photo by Ken Cole

All the classes that had correctly deciphered Ben Franklin's secret message were entered in the drawing for the PhysicsQuest grand prize (see story below). APS Executive Officer Judy Franz (left) picked the winner out of the drum as Head of Public Outreach Jessica Clark looked on.

"French help arriving soon in America." That was the correctly decoded (fictional) message from Ben Franklin that Maya Lampic's sixth grade class found when they had completed APS's PhysicsQuest 2006 learning adventure. Their correct answer, and a little luck, won them the grand prize: an iPod shuffle for each student, as well as some other prizes for the class.

The 20 sixth grade girls from Chicago were among thousands of middle school students who have decoded the message as part of PhysicsQuest, APS's mystery-based science kit for middle school students. Those classes that submitted the correct answers were entered in a random drawing to win prizes.

The 2006 PhysicsQuest mystery centered on Benjamin Franklin, in celebration of the 300th anniversary of his birth. The kit included materials and instructions for four experiments inspired by Franklin's work with lenses, electricity, and heat absorption. Each experiment gave students a clue they needed to decode the secret message.

However, a typo in the manual caused some classes to come up with the message, "American delicacies I now miss especially." APS accepted either answer as correct.

Last fall, 8700 kits were sent to 2120 teachers (teachers could register more than one class). Kits are free to teachers who request them. By the March 2 deadline, 900 classes had submitted

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Reliving the Good Old Days of Superconductivity

Twenty years after the Woodstock of Physics session at the 1987 APS March Meeting in which researchers presented results on recently discovered high temperature superconductors, many of the scientists involved returned to speak at the 2007 March Meeting. They reminisced about that exciting time and commented on progress since then.

This year also marks the 50th anniversary of the BCS theory of superconductivity. Speakers at a special evening session at the March Meeting spoke about the history and impact of that theory.

The events leading up to the Woodstock of Physics conference began in 1986 when Georg Bednorz and Alex Muller, at IBM Zurich, made their discovery of a lanthanum-based cuprate perovskite that superconducts at 35K.

At the 2007 March Meeting, Bednorz recounted how he and Muller had worked for months on the project before making the discovery. They were working with copper oxides, rather than conventional metallic alloys, and had tried material after material with no success. It was frustrating at times, but they kept going, Bednorz said during the 2007 press conference. "We didn't know whether it would be successful." So he and Muller kept the work low key, working after hours, using colleagues' equipment.

Finally, they hit upon a La-Ba-Cu-O compound. Initially they had seen only hints of superconductivity, and colleagues were skeptical that this unlikely ceramic compound would superconduct. By October 1986, however, they had found the optimum composition and had observed that the material exhibited the Meissner effect, considered definitive proof that the compound was superconducting, and they sent their paper off for publication. They won the Nobel Prize in 1987.

What made the discovery so exciting, said Bednorz, was that superconductivity had been known about and studied for decades, since Kamerlingh Onnes first discovered the phenomenon in 1911. "The excite-

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Physicists Present Latest Results in Graphene and Metamaterials Research

Cutting-edge research on new materials is a major focus of the annual APS March Meeting, and the 2007 conference in Denver was no exception. Among the more interesting highlights was a series of papers reporting new results in the areas of metamaterials–also known as "left-handed materials"–and graphene.

Metamaterials are amalgams of tiny rods, strips and rings that exhibit a negative index of refraction, thanks to their unusual, nanoscale-engineered architecture, which enhances the magnetic interaction between light and matter. To bring about a negative-index condition, the material's electric permittivity must be negative, and in some cases, also its magnetic permeability.

Metamaterials made their debut at the APS March meeting in 2000. At the time, only a couple of research groups were working in this area; today there are dozens investigating ways to exploit the unique properties of these materials to produce perfect lensing and other odd optical properties.

At the APS meeting in Denver, Purdue University's Vladimir Shalaev reported on a new record-setting metamaterial that might be ideal for so-called "superlensing": a process in which a thin flat panel of the metamaterial would be able to image an object at a spatial resolution better than the wavelength of the illuminating light. Ever since metamaterials were first realized in the laboratory, physicists have been pushing the boundary of these "left-handed" materials to shorter and shorter wavelengths.

Shalaev and his colleagues have reported a negative-index material operating at a wavelength of 770 nm, the shortest yet observed for a single-negative material (exhibiting only negative permittivity). Using the same material with a different

GRAPHENE cont. on page 6

Session Explores New Sources of Oil and Gas

Heavy oils and natural gas hydrates, which exist in vast reserves, could potentially become a significant source of energy, but these resources are much more difficult and expensive to produce than conventional sources of oil and natural gas. At a March Meeting session on the future of fossil fuels and a related press conference, speakers provided assessments of these potential alternative sources of oil and natural gas.

Natural gas consumption has been rising rapidly, and is expected to increase 70% by 2025, said Timothy Collett of USGS. The United States currently consumes about 25 trillion cubic feet of natural gas per year.

An alternative could be found in gas hydrates, reported Collett. Hydrates are ice-like solids, in which water molecules trap the methane molecules in a cage-like structure. Hydrates look a lot like ordinary ice, but they burn when lit with a match.

Like conventional natural gas, most gas hydrates are methane-based, and thus produce relatively clean burning fuel. Burning methane adds less carbon dioxide to the atmosphere than burning coal or oil.

Hydrates, first discovered in 1983, can be found on the sea floor near the coasts and underneath the arctic tundra. Earth contains vastly more natural gas in hydrates than in conventional natural gas, said Collett in a press conference at the March Meeting. "Hydrates are a very large, known source of natural gas," he said. There has been increasing international interest in recovering and using these resources, he said.

Several missions have recently explored some of these deposits and estimated how much natural gas hydrate they contain. Estimates range from 100,000 to 300,000,000 trillion cubic feet of gas hydrates on Earth, compared with 13,000 trillion cubic feet of conventional natural gas. The US has about 320,000 trillion cubic feet of gas hydrates, but only 1200 trillion cubic feet of conventional natural gas reserves.

More research is underway to assess more accurately how much hydrate natural gas exists and how much of it might be recoverable, Collett said.

Recovering the gas is challenging, but possible. Several research projects have shown that gas hydrates

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March Prize and Award Recipients

Photo by Cronin Photography

Front row (l to r): Franz Himpsel, Gabor Somorjai, Mark Kryder, Joel Miller, Arthur Epstein, John King, Edwin L. Goldwasser. Middle row (l to r): Uri Haber-Schaim, Chengkun Huang, William Wootters, Daniel Frenkel, Brooks Harris, Allan MacDonald, Samuel Bader, Kent Irwin. Back row (l to r): Hugh Churchill, Huanqian Loh, James Eisenstein, Timothy Zwier, Irfan Siddiqi, F. Bary Malik, Steven Girvin, Darrin Pochan, Glenn Fredrickson.

Members in the Media

"Islands are special. They're isolated from urban predators, and that includes people."

***Ralph Nobles**, on an island in San Francisco Bay that he thinks should be protected,* San Francisco Chronicle, *March 15, 2007*

"It seems a little unfair to the people whose last names begin with 'W,' doesn't it?"

***Stanley Whitcomb**, Caltech, on listing the authors alphabetically on a paper by a large collaboration,* Wall Street Journal, *March 16, 2007*

"There's a tremendous amount of work building the apparatus, getting the experiment to work. But sitting there late at night in the lab, and knowing light is going at bicycle speed, and that nobody in the history of mankind has ever been here before–that is mind-boggling. It's worth everything."

***Lene Hau**, Harvard University,* Boston Globe, *March 17, 2007*

"We're not a charity. We're not a poor small struggling school in the South that's going to fail if you don't give it money. I also make the case that not all black men are in danger of falling off a cliff."

***Walter Massey**, Morehouse College, on raising money for the college,* The New York Times, *March 28, 2007*

"That is based on the assumption that nobody can crack it in time. There is no proof of it. You can only hope [it doesn't happen]."

***Wolfgang Tittel**, University of Calgary, explaining that current data security measures rely on the fact that computers are not fast enough to decode information,* The Globe and Mail, *April 3, 2007*

"The glass bulb would be red-hot in the flame, and then they'd take the tube out of their mouth for a moment and the thing would go, 'woooo,' It would just sing to them."

***Greg Swift**, Los Alamos National Lab, on an observation by 19th century glassblowers,* Associated Press, *April 2, 2007*

"When you pay for your children, you send them to school; you pay a lot of money for them. You never expect that tomorrow they will pay you back and you will get some return. I think the attitude of the general public to physics should be like the attitude of parents to children. We do it for the future."

***Yuri Kamyshkov**, University of Tennessee, on why the public should fund physics,* Black Hills Pioneer, *March 23, 2007*

"The Iditarod bug didn't bite me. It swallowed me whole."

***Eric Rogers**, on running the Iditarod,* Anchorage Daily News, *March 17, 2007*

"We took a pratfall on the world stage. What the analysis shows so far is that something extraordinarily simple was missed in the design: the obvious imbalance of axial forces that can occur."

***Pier Oddone**, Fermilab, on the failure of a magnet built at Fermilab for the LHC,* Associated Press, *April 3, 2007*

The Ethiopian Connection

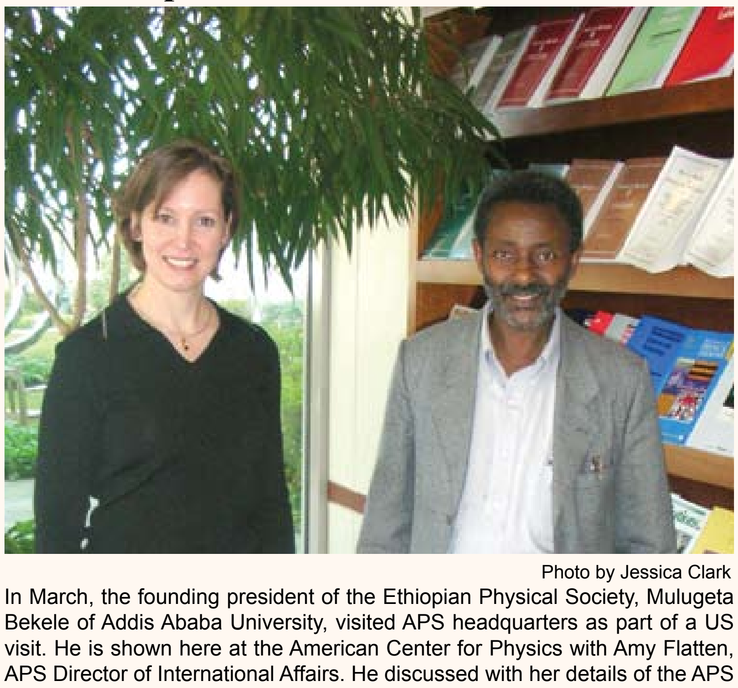

Photo by Jessica Clark

In March, the founding president of the Ethiopian Physical Society, Mulugeta Bekele of Addis Ababa University, visited APS headquarters as part of a US visit. He is shown here at the American Center for Physics with Amy Flatten, APS Director of International Affairs. He discussed with her details of the APS program that enables Ethiopian institutions (as well as others in Africa) to receive free online access to APS journals, a valuable resource because of the good broadband access that these institutions possess.

This Month in Physics History

May 1932: Chadwick reports the discovery of the neutron

By 1920, physicists knew that most of the mass of the atom was located in a nucleus at its center, and that this central core contained protons. In May 1932 James Chadwick announced that the core also contained a new uncharged particle, which he called the neutron.

Chadwick was born in1891 in Manchester, England. He was a shy child from a working class family, but his talents caught his teachers' attention, and he was sent to study physics at the University of Manchester, where he worked with Ernest Rutherford on various radioactivity studies.

In 1914, Chadwick decided to travel to Germany to study with Hans Geiger. Unfortunately, not long after he arrived, WWI broke out and Chadwick ended up spending the next four years in a prison camp there. This did not entirely stop his scientific studies. To keep from being bored, he and some fellow prisoners formed a science club, lectured to each other, and managed to convince the guards to let them set up a small lab. Though many chemicals were hard to get hold of, Chadwick even found a type of radioactive toothpaste that was on the market in Germany at the time, and managed to persuade the guards to supply him with it. Using some tin foil and wood he built an electroscope and did some simple experiments.

AIP Emilio Segre Visual Archives

James Chadwick

After the war, Chadwick returned to England, where he finished his PhD in Cambridge in 1921 with Rutherford, who was then Director of Cambridge University's Cavendish laboratory. Chadwick was able to continue to work on radioactivity, now with more sophisticated apparatus than tin foil and toothpaste. In 1923, Chadwick was appointed assistant director of Cavendish Laboratory.

Rutherford had discovered the atomic nucleus in 1911, and had observed the proton in 1919. However, it seemed there must be something in the nucleus in addition to protons. For instance, helium was known to have an atomic number of 2 but a mass number of 4. Some scientists thought there were additional protons in the nucleus, along with an equal number of electrons to cancel out the additional charge. In 1920, Rutherford proposed that an electron and a proton could actually combine to form a new, neutral particle, but there was no real evidence for this, and the proposed neutral particle would be difficult to detect.

Chadwick went on to work on other projects, but kept thinking about the problem. Around 1930, several researchers, including German physicist Walter Bothe and his student Becker had begun bombarding beryllium with alpha particles from a polonium source and studying the radiation emitted by the beryllium as a result. Some scientists thought this highly penetrating radiation emitted by the beryllium consisted of high energy photons. Chadwick had noticed some odd features of this radiation, and began to think it might instead consist of neutral particles such as those Rutherford had proposed.

One experiment in particular caught his attention: Frédéric and Irène Joliot-Curie had studied the then-unidentified radiation from beryllium as it hit a paraffin wax target. They found that this radiation knocked loose protons from hydrogen atoms in that target, and those protons recoiled with very high velocity.

Joliot-Curie believed the radiation hitting the paraffin target must be high energy gamma photons, but Chadwick thought that explanation didn't fit. Photons, having no mass, wouldn't knock loose particles as heavy as protons from the target, he reasoned. In 1932, he tried similar experiments himself, and became convinced that the radiation ejected by the beryllium was in fact a neutral particle about the mass of a proton. He also tried other targets in addition to the paraffin wax, including helium, nitrogen, and lithium, which helped him determine that the mass of the new particle was just slightly more than the mass of the proton.

Chadwick also noted that because the neutrons had no charge, they penetrated much further into a target than protons would.

In February 1932, after experimenting for only about two weeks, Chadwick published a paper titled "The Possible Existence of a Neutron," in which he proposed that the evidence favored the neutron rather than the gamma ray photons as the correct interpretation of the mysterious radiation. Then a few months later, in May 1932, Chadwick submitted the more definite paper titled "The Existence of a Neutron."

By 1934 it had been established that the newly discovered neutron was in fact a new fundamental particle, not a proton and an electron bound together as Rutherford had originally suggested.

The discovery of neutron quickly changed scientists' view of the atom, and Chadwick was awarded the Nobel Prize in 1935 for the discovery. Scientists soon realized that the newly discovered neutron, as an uncharged but fairly massive particle, could be used to probe other nuclei. It didn't take long for scientists to find that hitting uranium with neutrons resulted in the fission of the uranium nucleus and the release of incredible amounts of energy, making possible nuclear weapons. Chadwick, whose discovery of the neutron had paved the way for the atomic bomb, worked on the Manhattan Project during WWII. He died in 1974.

APS NEWS

Series II, Vol. 16, No.5
May 2007

Coden: ANWSEN ISSN: 1058-8132

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APS News (ISSN: 1058-8132) is published 11X yearly, monthly, except the August/September issue, by the American Physical Society, One Physics Ellipse, College Park, MD 20740-3844, (301) 209-3200. It contains news of the Society and of its Divisions,Topical Groups, Sections and Forums; advance information on meetings of the Society; and reports to the Society by its committees and task forces, as well as opinions.

Letters to the editor are welcomed from the membership. Letters must be signed and should include an address and daytime telephone number. The APS reserves the right to select and to edit for length or clarity. All correspondence regarding APS News should be directed to: Editor, APS News, One Physics Ellipse, College Park, MD 20740-3844, E-mail: letters@aps.org.

Subscriptions: APS News is an on-membership publication delivered by Periodical Mail. Members residing abroad may receive airfreight delivery for a fee of $15. Nonmembers: Subscription rates are available at http://librarians.aps.org/institutional.html.

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Columnar Jointing Gives Rise to Natural Wonders

The famed Giant's Causeway in northern Ireland is justly considered to be one of the seven wonders of the United Kingdom. Local legend holds that the causeway is the remnant of a bridge spanning the channel between Ireland and Scotland, built by an Irish giant named Fionn mac Cumhaill (Finn McCool).

The causeway consists of nearly 40,000 interlocking basalt columns, some as tall as 36 feet. The tops of the columns from "stepping stones" leading from the foot of the cliffs before disappearing under the sea. It looks far too regular in terms of its patterned structure to have been caused by natural processes–yet it was.

A fellow of Trinity College named Sir Richard Bulkeley II officially announced the causeway's existence in 1693, in a presentation before the Royal Society of London. Theories abounded as to how the causeway had formed. In 1771, a Frenchman identified only as Demarest announced that it was the result of volcanic activity.

According to physicist Lucas Goehring of the University of Toronto–who presented a paper at the 2007 APS March Meeting in Denver describing his recent work in this area with fellow Toronto colleague Stephen Morris–the columnar joints that make up the causeway were formed roughly 60 million years ago by the cooling and shrinking of molten lava from a massive volcanic eruption.

When the lava flowed into the sea, it quickly cooled, contracted, and crystallized into the near-perfect hexagonal columns we see today. (In fact, geologists believe there were three major lava flows, giving rise to lower, middle and upper basaltic layers, with the causeway columns occurring in the middle layer.) That kind of shrinkage inevitably causes stresses that fracture the rock.

"The columns are formed as a sharp front of cooling moves into the lava flow, assisted by the boiling of groundwater," said Goehring. "As the front advances, it leaves behind a crack network which evolves into an almost hexagonal arrangement. This network carves out the columns."

Similar structures can be created with a simple kitchen experiment: mix equal parts corn starch and water and place into a coffee cup. Dry the mixture by shining a bright light above it. Within a week or so, the mixture will be completely dry and you can break it apart to reveal an interior that is broken up into "starch columns."

In addition to studying the genuine article *in situ* in both Ireland and Scotland, Goehring and his cohorts have figured out how to control this tabletop kitchen experiment so precisely that they can study the formation process in much greater detail than scientists could in the past, augmented by X-ray tomography to give the first genuinely 3D imaging of the internal structure of the columns.

Among the more surprising findings: (1) the columns are not quite as perfectly hexagonal as previously believed, and (2) the continuous dynamics of the formations can be found even deep inside the structure, similar to dry foams. Also, the size of the columns depends on the speed at which the cracks advance, and the rate at which the water can move through the starch. That's why lava-formed columns are 1000 times larger than the tabletop experiment: the analogous properties of lava are much slower.

The Giant's Causeway

Sharing the session with Goehring was Meredith Betterton of the University of Colorado, Boulder, who became enthralled by the large icy spikes–called penitentes because they resemble a procession of white-hooded monks–she observed while viewing glaciers in the Andes.

Along with colleagues at the Ecole Normale Superieure in France, Betterton created the first artificial versions of these spiky ice formations, which can be found quite frequently on high-altitude glaciers where the air is particularly dry. She also devised a mathematical model to predict the process. The hope is that this research will yield useful insights into how glaciers evaporate; it may also lead to a practical strategy for preserving glaciers in light of global warming.

Penitentes arise when the sun's rays evaporate snow in such a way that the ice turns directly into water vapor, without melting into water first. The process is called sublimation. The snowy surface might start out smooth, but it gradually develops depressions as some areas sublimate faster than others, and the resulting curved surfaces concentrate more sunlight and speed up the sublimation even more, leaving behind a forest of towering spikes of ice. Penitentes are nature's ice sculptures.

Rising temperatures slow the formation of penitentes quite a bit, an especially alarming factor in light of global warming, because fewer ice spikes could accelerate the melting of glaciers. The spikes cast shadows, and serve as a natural cooling mechanism. There's a working hypothesis that spreading a small layer of dirt over glaciers could help preserve them by fostering faster formation of penitentes.

This turned out to be true with the small-scale versions Betterton created in her lab. She spread printer toner on her artificial snow layer to simulate pollutants common to glaciers around the world, and found that the ice spikes grew more rapidly as a result. It's a bit counter-intuitive, since carbon-based pollutants actually increase melting rates on glaciers because the ice absorbs more sunlight and therefore heats up more quickly. The formation of more penitentes could offset that damage.

Nose Out of Joint

Photo by James Riordon

Tim Gay's nose is out of joint because, as shown in the picture, he tried, and failed, to balance a gyroscope on the tip of it. Gay, professor of physics at the University of Nebraska, was giving a public lecture at the APS March meeting on "the physics of football"; he has written a book with the same title, and is celebrated for his video spots shown at halftime on the stadium jumbotron during Nebraska football games. The gyroscope on his nose was meant to demonstrate conservation of angular momentum, but even though it fell off, the audience of several hundred, which included many school-age children, enjoyed the lecture and seemed to appreciate how much physics there is in blocking, tackling, punting and passing.

SUPERCONDUCTIVITY continued from page 1

ment is that even in an established field, revolution is still possible," he said.

The initial high T_c discovery was confirmed by a Japanese group and then by Paul Chu of the University of Houston. Chu discovered Y-Ba-Cu-O, the first compound to superconduct above liquid nitrogen temperature. While working towards the discovery, he went many nights with only three hours of sleep, and only saw his family at Christmas, Chu recalled at this year's meeting.

By March 1987, dozens of research groups were working on similar high T_c compounds. About 50 physicists spoke at the marathon "Woodstock of physics" session held at the APS meeting in New York that year. Two thousand physicists packed the room and overflowed into the hallway until after 3 am, when the session finally ended.

The public was excited too, expecting this development would lead to amazing applications such as extremely efficient power transmission and superfast levitating trains. Paul Grant, who was at IBM Almaden in 1987, said in the 2007 press conference that even high school students got in on the high T_c excitement by producing one of these relatively simple compounds in their own school lab. Grant also remembered how physicists were treated like rock stars for that short period of time. For instance, bouncers at trendy New York nightclubs brought physicists to the front of the line. All they had to do was show an APS meeting badge.

Speakers at the 2007 March Meeting also discussed progress since 1987. Since then, more than 100 high T_c materials have been discovered. Y-Ba-Cu-O is still best for many applications, Chu said. Under pressure, Y-Ba-Cu-O still holds the record for highest T_c, at 164K.

Many questions remain about high temperature superconductivity, and many of the expected applications have not appeared, speakers pointed out. At the time nothing seemed impossible; more great developments were expected to be just around the corner. But while engineers have made a number of minor improvements in high T_c materials, there have been no major breakthrough in the past 20 years. No one has made a room temperature superconductor, and it is not known whether such a material is possible.

There are some applications for the high T_c materials, but no company is making a profit on high temperature superconductivity, said Grant. Chu predicted that high T_c wires might actually first be used by developing countries that don't already have a power infrastructure.

Moreover, there is still no accepted theory that explains high temperature superconductivity, making it an important unsolved problem, speakers said. "It rivals the unification of the forces," Grant said.

Although there is no explanation for high temperature superconductivity, conventional low temperature superconductors are explained by the BCS theory, which celebrates its 50th anniversary this year. A special evening session at the March Meeting commemorated that anniversary.

In 1957, John Bardeen, Leon Cooper, and Robert Schrieffer developed the first complete microscopic theory of superconductivity. In the theory, electrons form "Cooper pairs" that move in a coordinated manner. At the March Meeting, Doug Scalapino of the University of California, Santa Barbara, said the BCS theory was a major milestone. "It was a remarkably complete description." He said. "I think they changed the way we think about condensed matter physics."

Quantum Leap Reported for Entangled Photons

General purpose quantum computers may still be a long way in the future, but a number of advances in quantum computing and quantum information were presented at the March Meeting.

For instance, Anton Zeilinger of the University of Vienna has transmitted a quantum key wirelessly over a distance of 144 km, between two of the Canary Islands. This is the longest distance quantum information has been transported through the air.

Zeilinger reported the record-breaking feat at the March Meeting. He and his research group produced entangled photons on the island La Palma, then sent one of the photons through the air to a receiving telescope on Tenerife, 144 km away.

The European Space Agency operates telescopes on those islands, located off the coast of Africa. The telescopes were ideal for the application because they are sensitive enough to detect single photons.

The photons' polarization states, representing 0s and 1s, form a quantum key, a string of bits used to decode a message in a quantum cryptography scheme. A quantum encrypted message would be essentially unbreakable, since any attempt at eavesdropping would destroy the message, making the eavesdroppers presence known.

In a press conference, Zeilinger likened the entangled photons to a pair of "quantum dice," that would always show the same number no matter how far they are separated.

Earlier this year the group reported having transmitted a quantum key using pulses containing more than one photon. At the March Meeting, they reported for the first time the transmission of single photons, which are more secure.

The rate of data transmission through the air was slow, at just 178 photons in 75 seconds.

Zeilinger says this experiment demonstrates the possibility of sending messages over much longer distances. He is now proposing a more ambitious scheme of using satellites or the International Space Station to relay quantum communications between two locations on Earth.

In addition to sending quantum codes over longer distances, Zeilinger is planning to set up a real quantum cryptography network in Vienna. Five participating groups would each build the hardware for their own nodes, and they would then be able to send each other quantum encrypted messages across the city. Zeilinger hopes to launch the network in 2008.

Quantum cryptography systems are commercially available, Zeilinger pointed out, but as far as he knows they have only been used for research, not for encrypting data.

Several groups reported at the March Meeting on progress towards quantum computers.

David Wineland of NIST leads one of several groups working on ion trap quantum computing, currently one of the most advanced quantum computation technologies.

In these systems, ions are trapped with electric fields, and then manipulated with lasers to act as qubits. Wineland and other researchers have been working to reduce the size of these traps, because smaller traps would enable faster computers, Wineland said. However, the ions tend to overheat in small traps. Wineland's design, with all electrodes on a single layer, resembles a computer chip. It could potentially reduce the overheating problem and serve as a building block for a larger quantum computer.

Also at the meeting, Jian-Wei Pan of the University of Heidelberg and Hefei National Laboratory in China, described his 6-photon quantum computer. He said his goal is to have a ten-photon quantum computer in five years.

Researchers generally agreed that a practical quantum computer is a distant goal. "It's far too early to say what a future quantum computer will look like," commented Zeilinger during the press conference.

Letters

Correcting the Record on Pauli

I read with interest the "This Month in Physics History" column in the January *APS News* on Wolfgang Pauli and the exclusion principle. Although the article is essentially correct, fair and accurate, I have a few little objections to it. In particular:

1) In January, 1925, as stated, Pauli formulated the exclusion principle, BUT it was of course in the frame of the Old Quantum Theory.

Hence, the first statement is NOT forbidding fermions to be in the same quantum STATE. What Pauli said is this: There cannot be two electrons with the same four quantum numbers.

2) I am not aware of Pauli being disconcerted with the Old Quantum Theory of Sommerfeld. On the contrary, he for example encouraged Heisenberg to work on it. Later he wrote a masterly exposition of the Old Quantum Theory for the first edition of the Handbuch der Physik (1925).

3) The first clear attribution to the spin, as an internal angular momentum responsible of the electron's fourth quantum number is by the US physicist Ralph Kronig, who in January, 1925 was in Tübingen, Germany when Pauli was visiting. Actually, Pauli, in his usual sarcastic way, rejected Kronig's idea right away, saying it was a "good joke" (the full story, narrated by Kronig, is in "Sources of Quantum Mechanics" edited by van der Warden). In fact, Kronig was a bit angry with the later Uhlenbeck-Goudsmit hypothesis, as he had advanced it before.

4) It is not true that "... In the two years after Pauli's ...exclusion principle, the new quantum mechanics took off..."

Here's the record: Heisenberg's decisive Quantum (Matrix) Mechanics was ready in June, 1925, and appeared during that summer. Dirac's important contribution (conmutators from Poisson brackets) is of November, 1925, and even Erwin Schrödinger's wave mechanics is of January, 1926. Not two years later.

5) Among the many things due to Pauli you omit, the most important one is that, with Heisenberg, he was responsible for the formulation of Quantum Theory of Fields, in two papers in 1929 and 1930.

6) It is true that he devoted a lot of time and energy to philosophical and other issues, but that was throughout his whole life, not only at the end, and until the very end, he was concerned with fundamental physical problems: in 1955 he produced a fundamental paper on the CPT theorem, and even replied by letter, in early 1957, to the news of parity violation.

Luis J. Boya
Zaragoza, Spain

Not Every Experiment Has to be Done

Mehrdad Adibzadeh (Letters, March *APS News*) writes, "What is disturbing... is the claim that an almost-effortless experiment would have a certain outcome to support a certain point of view, when it apparently has never been carried out." While I agree that this is disturbing, allow me to point out that this statement applies not only to claims of humble versus arrogant scientists, but also to so many of the thought experiments of the early 20th century on the foundations and interpretation of quantum mechanics, thought experiments that can be found in many classic textbooks on quantum mechanics.

N. Sukumar
Troy, NY

Claims for Wind Power Greatly Overblown

The letter by Mike Jacobs [*APS News*, March 2007], which touts wind energy as a viable contribution to solving our energy problems, contains several mistakes and omissions that are not apparent in a non-technical discussion. To judge what wind energy can actually contribute, one has to work with realistic numbers.

I illustrate this with the example of the 150-MW wind park planned in the Gulf of Mexico opposite Galveston, Texas (at a cost of $300 million). This park will deliver, at best, at the rate of 30 MW. Comparing with the actual energy use of Texas, this will provide electrical power for less than one extra minute per day for Texas. Moreover, if one wants to keep up with a 1.5% annual increase in electrical usage in Texas by installing only wind power facilities, one would have to build about 25 of these wind parks every year!

The reasons that in an actual comparison with conventional power generation, wind energy performs so dismally are the following: 1. Air is a very dilute medium that moves at low speeds. 2. The energy that can be extracted from the wind varies as the 3rd power of the wind speed; so, for example, if the wind speed drops by one half, the energy drops by a factor of eight. As a result, wind turbines don't produce any energy for low wind speeds, i.e. below Beaufort 4 (a 'moderate breeze',12-18 mph, the prevailing wind in most cases). 3. Over a period of days the wind can be extremely variable so that energy is not produced in a steady stream but in a succession of spikes between zero and full power, which can create a serious challenge for the grid operators. The combined result of these facts is that the wind turbines deliver only a modest fraction (20-25%) of the installed power capacity.

Germany is half the size of Texas but has more than twice the installed wind power capacity of the *entire US*, namely 20,424 MW (in 2006). Nevertheless, the large investment in wind energy (16,394 MW in 2004), produced only 4.9% of Germany's electricity usage. The problems created by large investments in wind power are discussed honestly (a rarity) in the *Wind Report 2005* of E.ON Netz (Ref. 1), Germany's second largest electrical utility. One conclusion of the report is that the possibility of wind replacing conventional energy sources is quite limited. Germany's wind-energy system in 2004 could only contribute 8% of its output capacity (1312 MW) to secure production of the system. So an extra conventional generating capacity of about 90% of the installed wind capacity had to be available as backup. This requires an enormous additional investment.

The report also stated that the feed-in of wind energy can change often and quite dramatically. On Christmas Eve 2004, wind production in Germany fell 4000 MW in 10 hours, representing the capacity of eight 500 MW coal fired power plants! This created an enormous challenge for the operators of the grid and it could easily have led to a vast blackout in central Europe. About 7000 wind turbines spread out over Germany (from the North Sea to the Swiss border) were feeding into the grid, but Fig. 3 of Ref. 1, which displays the wind energy feed-in for the entire year, clearly shows frequent variations between 0.2% and 38% of the daily peak grid load. This contradicts what Jacobs asserts about a leveling effect of geographically dispersed wind turbines.

Production and usage of electrical energy must be completely matched at all times; any mismatch can lead to blackouts. In the case of the German system this can lead to blackouts covering large parts of Europe; it has come so close a couple of times that the Dutch and Polish grids were also threatened.

Jacobs' statement that Denmark manages to generate 20% of its electricity from wind "without storage and back-up capacity" is completely wrong; Norway and Sweden perform these functions for Denmark. Excess Danish wind energy is shipped to these countries where it relieves the load on the hydroelectric reservoirs; in turn electricity shortages in Denmark get replenished by these countries. Without these arrangements Denmark would be subject to many crippling black-outs. Finally, Jacobs' assertion that not a single MW of back-up capacity for wind energy has been required in the US is probably due to the fact that the US wind energy system consists of so many widely dispersed (relatively) small systems, so that the local base-load generators can still take care of any fluctuations. This will change in the future when a substantial fraction of the base load (e.g. 20%) is supposed to come from wind energy.

The E.ON Report should be required reading for all those people who think and say, "The more wind energy the better."

Reference

1. E.ON Netz *Wind Report 2005* (in English) available at www.eon-netz.com/EONNETZ_eng.jsp

Frits de Wette
Austin. Texas

Nepal Protest Brings Results

Regarding the picture with the headline "Getting high on physics", published in the March 2007 *APS News*, I would like to inform you that the number of students in the physics class at Tribhuvan University in Nepal has increased. This happened because of the demonstration by students on December 12, 2006 in front of Nepal's Ministry of Education and Sport, as shown in the picture, in which they demanded greater access to physics classes.

Tirtha Raj Joshi
Akron, OH

Editor's note: *The author, a master's student in physics at the University of Akron, is from Nepal.*

At APS, the Embargo Has Already Gone

"The Back Page" article in the March *APS News* last month entitled "The Embargo Should Go" urged that scientific journals not put embargoes on publicity relating to their articles. There has not been any embargo of news stories published in *Physical Review* and *Physical Review Letters* for over 22 years. See the Editorial by an earlier Editor-in-Chief [D. Lazarus, *Phys. Rev. Lett.* **52**, 2101 (1984)]. So APS members can be assured that our journals anticipated, and followed, the advice in the "Back Page" quite a while ago.

Gene Sprouse
APS Editor-in-Chief

INSIDE THE BELTWAY:
WASHINGTON ANALYSIS AND OPINION

Twelve-Year Term Limits Twelve Years Later

By Michael S. Lubell, APS Director of Public Affairs

A dozen years ago, flush with their victory in the 1994 congressional elections, the brash new Republican leadership brought H.J. Res. 73 to the floor of the House of Representatives. The resolution would have amended the United States Constitution by imposing 12-year term limits on members of Congress. Senators would have been able to serve a maximum of two full terms, and Representatives would have had to clean out their offices after six terms.

The House passed the bill by a 227 to 204 vote, with 189 Republicans and 38 Democrats supporting it and 40 Republicans, 163 Democrats and 1 Independent opposing it. But the initiative failed to garner the two-thirds majority needed for a Constitutional amendment, and it died formally, at least on the federal level. Still, in the frothy atmosphere of the 1994 "Newtonian" revolution, many members of Congress took a pledge to retire within twelve years, and amazingly some of them remained true to their principles. Count Republican Bill Frist of Tennessee, who last year was Majority Leader of the Senate, among them.

It's been twelve years since former House Speaker Newt Gingrich asked his colleagues to take the twelve-year pledge, and it's time to ask the question, do term limits make sense? Do the good public servants who took the pledge and followed through on their commitment deserve kudos? For being honest, reliable and principled, without a doubt! But beyond that, have they really done a good deed?

If you think that the best government is the least government, you'd probably say yes. Put in a few years of public service, get out and return to the real world, where markets dictate outcomes. And get on with a life that really counts.

"But wait, there's more!" as the late Arthur Schiff, king of the infomercial, used to say as he was slicing and dicing his way to riches peddling his Ginsu knife on late-night TV. Term limits minimize the creation of political fiefdoms and the entrenched policies that go along with them, providing, in the process, the opportunity for the constant churning that lets new ideas bubble up with regularity. Sounds so good, I'm almost ready to buy into it.

But just as I never bought a Ginsu knife, I'm not quite ready to strike the bargain. My experiences on the Hill the last four months will tell you why.

First scroll back to 2005. That January, amid much Washington hoopla, the Council on Competitiveness released its annual competitiveness report, raising questions about the nation's future economic status on the global stage. A month later, the Task Force on the Future of American Innovation issued its first R&D Benchmarks Report, containing trend lines that painted a grim picture of future U.S. competitiveness in the high-tech arena.

By early spring, key Senators and Representatives had become so alarmed that they asked the National Academies to set up a study panel and quickly recommend policy changes to address the issue. The panel, chaired by Norman Augustine, retired CEO of Lockheed-Martin, completed its work in less than six months, and their report, "Rising Above the Gathering Storm," was on the desks of Members of Congress and their staff by the end of October.

A month later, House Democrats issued their "Innovation Agenda" and the Senate began to

BELTWAY continued on page 5

Smart Organisms Use Physics To Find Their Food

The humble single-celled amoeba lacks access to a handy Zagat's guide when it comes to foraging for its food. But according to Liang Li of Princeton University, amoebae don't need one. They have a built-in mechanism for an optimal food-foraging strategy.

Li presented a paper on the topic at the 2007 APS March Meeting in Denver. For instance, scientists previously assumed that microbes move in random patterns unless they are specifically hot on the scent of tasty nibbles. Yet Li has found that species of amoeba called *Dictyostelium* seem to remember its previous "steps" and use that remembered information to explore new ground, thereby increasing their chances of finding food.

How can such a simple organism have any kind of memory at all? Li thinks there may be a clue in the mechanism by which the creature moves: namely, by rearranging its body into protruding shapes known as pseudopods.

Using phase contrast microscopy, Li tracked a teeming sample of *Dictyostelium* over 100 hours, charting the "runs" and "turns" they made, which formed a zigzag pattern of motion. She specifically looked at how often the creatures made a left turn followed by a right turn, and found they showed a clear bias for that kind of variation.

Li reported that the formation of pseudopods leaves temporary "scars" in the cell's cytoskeleton, and this makes it far more likely that the next pseudopod the creature forms will point in a new direction. Because it changes direction and doesn't retrace its steps, it covers more ground and increases its chances of finding food.

More complex, higher organisms, like zooplankton, have also evolved a highly efficient hunting strategy. Ricardo Garcia, with the Center for Neurodynamics at the University of Missouri in St. Louis, talked about his research on the role of specific swimming characteristics in achieving optimal food foraging strategies for zooplankton. The work is the first observation in a living animal of an inherent swimming characteristic–the turning angle–that optimizes the food obtained in a patch of fixed size for an organism foraging for a fixed time.

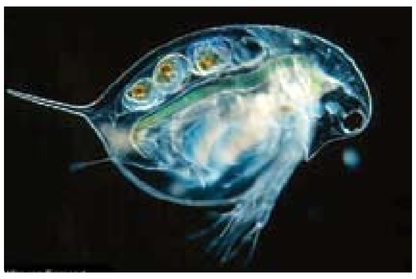

Photo by W. van Egmond

Daphnia

Garcia and his colleague, Frank Moss, studied the zooplankton *Daphnia*, more commonly known as water fleas. They looked at the swimming movements of five different *Daphnia* species of varying sizes, all of which exhibit a distinct hop-pause-turn-hop sequence while swimming. They analyzed the turning angles the creatures made after each hop in the sequence, plotting the number of times a given angle was observed on a histogram.

These turning angles were almost, but not quite, completely random–they found evidence of a preferred turning angle value, based on a mathematical analysis of the underlying random processes, or intensity of the "neural noise" in the water fleas.

Scientists have known for many years that biological systems frequently rely on stochastic resonance as a stimulus to the sensory systems, which in turn can affect the behavior of creatures both great and small–usually in positive, optimizing ways that improve the creatures' chances or survival. The neural noise of water fleas influences the turning angle in such a way as to enable the creature to explore the most amount of space and gather the most food within a given time frame.

The observed noise intensities correlate with the width of distribution of the turning angles favored by the water fleas, and it turns out that the creatures gather the most amount of food in a single foraging session at a very specific noise intensity. "A small noise intensity means that the animal obtains less than the maximum possible amount of food within its patch during its fixed feeding time," said Garcia. "Likewise, less food is ingested if the distribution is too broad." The findings were consistent across all five species of *Daphnia* studied, regardless of size or age of the organisms.

Garcia suspects that this natural stochastic resonance may have a played a significant role in the evolution of sensory systems, although he is careful to emphasize that his results don't outright prove this hypothesis; they merely offer strong supporting evidence in favor of that notion. In the case of *Daphnia*, Garcia believes that the water flea's distinctive swimming patterns evolved over tens to hundreds of millions of years via Darwinian natural selection.

Oklahoma High School Physics Student Wins Intel Science Talent Search

Mary Masterman, a 17-year-old student from Oklahoma City, beat out a field of 40 finalists and won the top award of the 2007 Intel Science Talent Search in March. She will receive a $100,000 scholarship from the Intel Foundation for building an accurate homemade Raman spectra system out of a laser, a digital camera, a variety of lenses, and a prism-like object to disperse light.

A senior at Westmoore High School, Masterman built her spectrograph system at home for $300, compared to the $20,000 to $100,000 price tag for high-end commercial systems.

Using a laser as her light source, Masterman tested several household objects and solvents–including acetone and toluene–and compared her results to published wave numbers. Even with her inexpensive laser light source, she found she could make relatively accurate wavelength measurements with her homemade device. She hopes to attend MIT or Caltech after graduation.

For a complete list of this year's winners, see http://www.intel.com/education.

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draft bipartisan innovation legislation. In short order the White House unveiled the American Competitiveness Initiative (ACI) that contained a blueprint for doubling the aggregate budgets of the Department of Energy's Office of Science, the National Science Foundation and the core programs of the National Institute of Standards and Technology. So imprinted had the competitiveness issue become, that by the summer of 2006, you couldn't find a House or Senate member or, for that matter, any legislative director in a congressional office, who hadn't heard about the "Gathering Storm" report or the ACI.

But by midnight on November 6, everyone on Capitol Hill knew that the congressional world was about to be set spinning.With the Democratic victory at the polls, the pecking order was about to change: the minority would become the majority; minor players would become major players; low-level staff would become high-level staff; the ins would become the outs. For the Republican Party as a whole, voters ironically had enforced the twelve-year term limit.

Periodic change is certainly good for government, but with change often comes a loss of institutional memory. Visit a congressional office today and mention the "Gathering Storm" report or ACI, and more often than not, staffers will give you a vacant stare. Talk to any one of the 54 new Representatives and 10 new Senators about innovation and competitiveness, and you will find consternation.

Six months ago, I was mulling over what issue I would personally turn to next, with the matter of science research and education and their connection to global competitiveness fairly well understood by the Hill. Term limits have changed all that. They may not be good for consistency in policy, but they keep lobbyists employed.

Physics Models Brought to Bear on Gene Transfer, Viral Vaccines

Something that continues to puzzle scientists about the fossil record is that single-celled life forms first appeared about 3.5 billion years ago, with another 2.5 billion years passing before multi-celled organisms finally made their debut on the scene. However, it took just 1 billion years for every other conceivable form of life to evolve: plants, mammals, birds, insects, reptiles and any other terrestrial species.

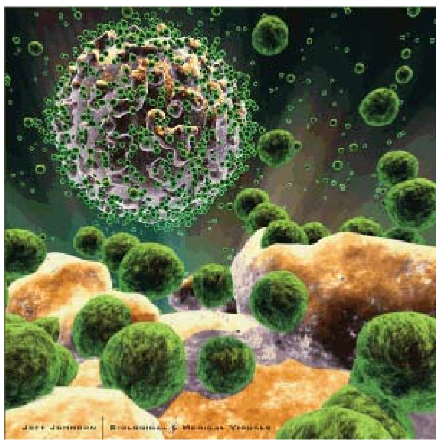
That's a significant increase in the rate of evolutionary development. The standard cited mechanisms for evolution are point mutations–"random changes in single nucleotides on the DNA chain, or genome"–and recombination, which occurs when the genetic sequences of a set of parents are recombined ("sexual selection"). But models that simply take into account these two common mechanisms really don't explain the sudden rapid acceleration of evolutionary rates indicated by the fossil record.

Enter Rice University physicist-turned-bioengineer Michael Deem, who has a penchant for adapting mathematical models from physics to the mutation and evolution of the flu virus, among other research. At the APS March Meeting in Denver, Deem reported that he has now developed "the first exact solution of a mathematical model of evolution that accounts for this cross-species genetic exchange." He attributes the phenomenon to horizontal gene transfer (HGT), in which the DNA from one species is introduced into another.

Deem found that by accounting for HGT–in addition to point mutations and sexual recombination–his model can demonstrate how HGT increases the rate of evolution by spreading favorable mutations across populations.

So it is possible to swap entire sets of genetic code, including the genes that allow bacteria to develop resistance to antibiotics–and for the human immune system to continually adapt to invasive species, an attribute Deem has traced to an HGT insertion that occurred some 400 million years ago. In fact, he thinks that a significant portion of our DNA was donated by viruses and bacteria that infected our ancestors over lots and lots of generations. "Life clearly evolved to store genetic information in a modular form, and to accept useful modules of genetic information from other species," said Deem.

Deem's prior work on flu vaccines–notably, the use of nuclear spin glass modeling to better predict which strain of the flu virus



HIV virus infecting a cell

was likely to dominate in any given year–exploited the phenomenon of "original antigenic sin." The antibodies produced by the body's immune system to fight exposure to the flu virus become part of the body's "memory" so that it can fight off future exposure to the same flu strain. However, those same antibodies end up suppressing the creation of new antibodies when the body is exposed to a new strain of the flu.

The phenomenon has also been observed in dengue fever and HIV. The latter was the topic of a second paper by Deem's research group presented at the Denver meeting. HIV is an especially difficult virus to eradicate, in part because it mutates so quickly after initial infection, producing several different virus strains. It's an ingenious "divide and conquer" strategy, according to Deem: the human immune system responds to viral infection by producing antibodies to ward off any given strain, but it tends to only focus on a single strain; the rest just run rampant.

T-cell competition takes two forms, per Deem's computer models: original antigenic sin (also known as "deceptive imprinting"), and immunodominance, which occurs when several viral strains simultaneously infect a single person. The cells that respond to each strain compete until one emerges the victor.

"Once the immune system chooses a winning set of T-cells, it has a natural tendency to go with those cells when it's confronted by new strains of the same disease in the future," said Deem. "For HIV, we found a direct correlation between the level of competition among T-cells and the rate at which the virus escaped."

Deem has devised a potential new strategy for a more effective HIV vaccine. He thinks that inoculating someone at various points on the body against different strains simultaneously could all but eliminate competition among T-cells, so that the HIV will be trapped in a permanently latent state, never raging out of control to develop into full-blown AIDS.

There are lymph nodes scattered throughout the body, responsible for producing those all-important T-cells, but it takes four or five days before any T-cells produced therein leave the node and spread throughout the body. Simultaneous inoculation would mean that each different node would select for a different strain, with no single T-cell emerging as dominant, because immunodominance doesn't have time to kick in.

Burn, Baby, Burn

Photo by Ed Lee

No, they're not trying to set the paper on fire with a magnifying glass. Adrian Carmichael and Jeff Osborne, two participants in the APS Teachers' Day at the March meeting, are performing a perfectly safe optics experiment. Seventy-seven teachers from the Denver area attended the day of workshops, talks, and networking.

Microbe-Based Sensors Can Improve Security

Physicists are finding new ways to improve security with astronomically inspired scanners and microbe-based sensors.

Jeffrey Brinker of the University of New Mexico and Sandia National Labs reported at the March Meeting a way to make microbe-based sensors that could be used for security applications. The project originally started when DARPA wanted to develop "insect reconnaissance." They approached Brinker, asking him to develop tiny biocompatible sensors that could be attached to the backs of bees or other insects.

The insect reconnaissance project never worked out, but the research did lead Brinker to develop a way to build tiny biocompatible nanostructures. Living calls can integrate themselves into those structures, which nurture and protect them. The living cells can be engineered to glow in the presence of chemicals or pathogens, and thus can be used as sensors for security applications.

Brinker make these structures by mixing up a solution of lipids and silica and living cells. As the solution dries into an ordered solid film, living cells such as yeast and bacteria can integrate themselves into the silica film, and can even direct the formation of the tiny structures that serve as protective houses for the microbes. Brinker calls the development a "new approach to engineering with life."

The structures protect the cells, and the lipids provide nutrients and keep the cells from drying out. The cells stay alive for weeks to months, even in harsh environments where they would not normally survive, such as in a vacuum or under an electron microscope.

Many of the tiny cells can be printed onto a surface to make arrays of sensors on tiny chips, he said.

The cells can be engineered to fluoresce in the presence of toxic chemicals, explosives or pathogens.

They can be used to detect just about anything, Brinker said. They could test water or air for chemical or biological weapons. They could also be used to study disease, for instance as a platform to study the onset of dormant diseases like tuberculosis, suggested Brinker.

In another security-related development, Panu Helisto, of VTT Technical Research Center of Finalnd, is working on developing terahertz radiation detectors that could be used for security scanners in airports or other places. The scanner, based on instruments long used in astronomy, would detect terahertz radiation people naturally emit.

It measures radiation using an array of superconducting microbolometers, niobium wires that heat up when they absorb radiation emitted by the subject. Most clothing materials are transparent up to about 1 THz, so a good THz detector could see through clothing to spot concealed weapons. These sensors could detect concealed weapons up to 100 meters away, so the technology could be used to scan people without their knowledge, said Helisto.

The scanners would not have high enough resolution to reveal anatomical details, making the technology appealing to both the public and the authorities. Images are similar to those created by infrared sensors, said Helisto. Unlike x-ray scanners, the sensors don't subject the person being scanned to any radiation, and so do not present any health issues, said Helisto.

Martian Features Provoke Sharp Debate

Geological features on Mars, including some strange sharp features called razorbacks, have been suggested as evidence of liquid water. However, granular materials researcher Troy Shinbrot of Rutgers University has found that these features could be produced by dry dust grains rather than flowing water. He reported his results at the March Meeting.

The pointy razorbacks, a few centimeters high and less than a centimeter wide, photographed by NASA's Mars rovers, have intrigued observers. Some scientists believe they may have been produced recently by flowing water. Other stream-like features on Mars have also been cited as evidence of water.

Shinbrot wondered whether these features could be associated with completely dry grains rather than flowing water. He created a simple setup to find out. He placed a pile of light, hollow glass beads in a box and tilted it. As the box is tipped, the light grains create a mini dust storm and eventually settle down. Shinbrot found that he could make the glass grains fall in patterns resembling many features seen on Mars, from wide apron-like features to thin sinuous streams.

Photo courtesy of NASA/JPL/Cornell

Razorbacks photographed by NASA's Mars rover Opportunity

Though the patterns in the lab experiment are on a much smaller scale than those on Mars, Shinbrot believes they are comparable because the grains settle slowly compared with the speed at which they flow downhill, as dust grains would in Mars' low gravity.

Sharp features resembling the razorbacks seen on Mars could also be produced in a similar setup in the lab by applying an electric field to the grains, Shinbrot found. When the box was tilted, some of the tiny grains clumped together as they became airborne, and landed in the spiky formations similar to Martian razorbacks. Electric fields could build up on Martian sand grains as they slide past each other because Mars is so dry, he reported. "These features that look like water may simply be dry features," said Shinbrot.

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light polarization, they achieved a wavelength of 815 nm, the shortest yet observed for a double-negative material (exhibiting both negative permittivity and permeability).

An even hotter research topic these days is graphene, essentially one-atom-thin carbon sheets. Physicists are also excited about the very unusual behavior of electrons moving through a graphene landscape: namely, you can increase the electrons' energy without increasing their velocity, almost as if the electrons were behaving like slow-moving light waves.

At last year's March Meeting in Baltimore, there were presentations on graphene by only a few groups. This year, there were dozens. Graphene-related research has exploded, thanks in part to its adaptable mechanical and electrical properties, with some 180 research papers published on the topic in the past year, mostly on the theoretical aspects, but progress has also been made on the experimental front.

In Denver, Pablo Jarillo-Herrero of Columbia University gave an overview of the latest experimental developments in this rapidly growing field. For instance, researchers have successfully developed graphene ribbons. Among the more interesting recent findings is that the resistivity of the material changes according to the width of the ribbons, which means that the semiconducting properties of graphene could be tailored to suit the application.

Jarillo-Herrero also summarized other recent progress in the field, including the observation of superconducting graphene transistors by researchers at Delft University in the Netherlands; freely suspended graphene sheets, a room-temperature Hall effect, and room-temperature single-electron transistors with graphene–the latter by a research group at the University of Manchester in England.

Advanced Lab Instructors Plan New Organization

A new association for advanced undergraduate physics laboratory instruction is being formed. At an initial session held at the 2007 March Meeting, participants shared plans and ideas for the organization.

The purpose of the new association will be to foster communication among advanced lab instructors and to provide some professional recognition for them.

"The group is trying to put the focus of the physics community back on advanced lab," said Jonathan Reichert, who is playing a leading role in starting the organization. Reichert is the president of TeachSpin, a company that makes instruments for physics laboratory instruction. The new association was initially the idea of Krishna Chowdary, now at Bucknell University, said Reichert.

Most universities do offer advanced labs for undergraduates, though there are some schools that don't.

These courses can be difficult and time-consuming to teach, and they require expensive equipment. In some cases, physics departments have very limited resources for these classes. People who teach these courses may feel isolated and unrecognized, so contact with other advanced lab instructors could be helpful, said Reichert. Members of the association could advise each other on improving these courses, selecting and using appropriate equipment, and convincing departments to purchase equipment, said Reichert.

The new association will give TeachSpin an opportunity to market its products, Reichert says, but members of the association will benefit as well.

At the March Meeting, about 35 people attended a reception for advanced laboratory instructors sponsored by TeachSpin and the APS Forum on Education. About 25 of the attendees indicated they were interested in joining the new association, at a cost of $10. TeachSpin will also contribute to the founding of the association. Recichert said he would like at least thirty people to sign up before the association is officially launched.

The association might meet a couple times a year, Reichert predicts. Lab instructors could bring their equipment and share ideas on implementing laboratory experiences, he envisions.

Once the organization is launched, Reichert expects some of the new members will take charge of leading the new organization and any committees it may form.

Wolfgang Christian of Davidson College is one physicist who plans to join the organization. "I have been teaching advanced laboratory off and on for 25 years and I think it important to share experiences and to pass on knowledge to new faculty," he said.

Another potential member is David Pullen of the University of Massachusetts, Lowell. He also looks forward to sharing ideas with members of the new organization.

There has been some attention paid to freshman labs, he said, but not so much focus on advanced lab, and this organization can help change that. He hopes the new organization will work with APS and AAPT.

Potential members are being asked to vote on a name for the new organization; possibilities include: Advanced Laboratory Physics Association (ALPhA), Consortium for Advanced Laboratory Instruction (CALI), and Advanced Physics Laboratory Association (APLA). For more information, contact Jonathan Reichert (jreichert@teachspin.com)

OIL & GAS continued from page 1

can be produced by either heating the hydrates or decreasing the pressure to release the gas. More testing of these methods is still needed, said Collett.

Environmental concerns associated with hydrate production include possible damage to the sea floor or possible accidental release of methane gas. Any project that produces gas hydrates would have to deal with these concerns, said Collett. However, accidental release of methane is unlikely, he said.

Based on the limited studies done so far, Collett believes hydrates could become economically competitive with conventional natural gas.

Another promising source of energy is heavy oil, Doug Schmitt of the University of Alberta reported. Significant heavy oil reserves exist in Canada, South America, and Colorado, while most of the world's light oil reserves are in the Middle East.

Heavy oil looks like sand with tar added, Schmitt said. Though heavy oil is abundant, because it is so thick–its viscosity is similar to peanut butter–it is difficult to extract and use. "The real problems are accessing it and being able to produce enough," said Schmitt.

Heavy oil can be extracted using a process called steam assisted gravity drainage. This involves drilling two horizontal bore holes and injecting steam into one of them. The steam heats the heavy oil, making it flow more easily. The process works, said Schmitt, but is costly.

In order to make the process as efficient as possible, Schmitt says it is important to improve our knowledge of the properties of the heavy oil and the surrounding rock. He and his group are using sensitive seismic imaging techniques to monitor the heavy oil production process. They have used these techniques to locate where the largest oil deposits are within the rock. They have also been able to trace the steam as it is injected during the extraction process, potentially making it possible to use the steam more efficiently. Alternative technologies to extract the heavy oil are also being investigated, Schmitt said.

Biomolecules Ready For Their Close-up with New Imaging Methods

Physicists are constantly developing new and improved methods to get better pictures of cancer cells and protein molecules that are so critical to human health. Two such methods were described by speakers at the APS March Meeting in Denver.

Cancer cells, for instance, shimmer impressively for CCD cameras when imaged with a new technique called digital holographic imaging. It produces time-lapsed, dynamic speckled images that "shimmer" in response to cellular motion. Recent work at Purdue University marks the first time holography has been used to study the effects of a drug on living tissue, according to David Nolte, the Purdue University physics professor who headed up the research.

Conventional microscopy techniques don't delve very deeply into tissue. Nolte wanted to get a peek inside the tissue itself, preferably at a depth of about 1 millimeter, to gain a better understanding of its structure.

He has combined holographic imaging with laser ranging, which measures how long it takes for a laser pulse to travel to an object and be reflected back. "The holography gives us the peaks and valleys and detailed depth information, while the laser ranging allows us to control how deep we are looking," he said.

Nolte's new imaging technique measures the motion of organelles inside cancer cells to determine whether they're living or dead. Organelles play a key role in fostering the out-of-control cancer cell division that so often proves fatal to the patient.

His imaging system creates a hologram of a tumor whose center is usually filled with necrotic tissue surrounded by an outer shell where the cells madly multiply with wild abandon. Laser light shines on both the object and the CCD camera, and the reflected light is fed into the system, which records very detailed information about depth and motion of the components at work in the tumor tissue.

All that outer shell activity shows up as a bright shimmer in the resulting image, while the dead tissue at the center doesn't move at all (What little shimmer there is at the center can be attributed to the incidental motion of the CCD cameras recording the experiment). Using this technique, it's possible to create handily color-coded "motility maps" of cellular activity at three different tissue depths: 120, 190, and 330 microns. Red indicates high activity, and is found at 120 microns. By 330 microns, that activity has slowed sufficiently that the contrast color is predominantly yellow. Completely dead tissue shows up as blue.

So cellular motion becomes a built-in contrast agent used to enhance the image, making digital holographic imaging a vital emerging tool in measuring the effectiveness of anti-cancer drugs like colchicine. If the drug is working, there will be a reduction in the motion of the organelles, which will show up with less shimmer in the image on the computer display, and can then be quantitatively analyzed.

"We have moved beyond achieving a 3D image to using that image for a direct physiological measure of what the drug is doing inside cancer cells," said Nolte. "This provides valuable information about the effects of various doses of the drug and the time it takes each dose to become significantly affected."

Nolte's isn't the only research group finding innovative new ways to image biological molecules. Andre Brown of the University of Pennsylvania has employed the force sensing mode of standard atomic force microscopy to image molecules of fibrin, a protein that acts as a molecular spring to keep blood clots structurally stable, but still flexible enough to allow blood to flow through them.

Fibrin develops in the blood from another protein called fibrinogen, when blood cells release the enzyme thrombin in response to encountering damaged tissue.

Last year, researchers at Wake Forest University, Harvard, and the University of North Carolina used AFM to test the stretchiness of fibrin, and found these fibers can stretch much further before breaking than other biological fibers–including collagen, spider silk, and keratin. That property is crucial to fibrin's ability to stop the flow of blood, which exerts a great deal of mechanical stress on the fibers. There have also been studies demonstrating that fibrinogen taken from patients with heart problems forms stiffer clots than that taken from healthy control patients.

Brown saw an intriguing correlation between heart disease and the mechanics of fibrin in blood clotting, and thought that protein unfolding might play a role in the unusual elasticity ("stretchiness") of fibrin fibers. He used AFM in combination with total internal reflection fluorescence microscopy to measure the force with which this unfolding occurs–marking the first time the mechanics of fibrinogen has been measured at the single molecule level.

He found that protein unfolding does indeed seem to play a role in the mechanics behind blood clotting. Next on the agenda is to explore whether this unfolding plays any kind of role in clot mechanics at more modest extensions.

PHYSICSQUEST continued from page 1

answers, 290 of which were correct. Those that sent in the correct answers were eligible for a random drawing to win prizes. All classes that submitted results received a certificate of participation.

The five first place classes received PhysicsQuest journals, a gift card for science-related materials supplies, and a skyrail suspension kit. Maya Lampic's 6th grade class, at Sacred Heart Schools in Chicago, won the grand prize: iPod shuffles, a $500 gift card for science-related materials for the class, PhysicsQuest journals, and a skyrail suspension kit.

Lampic and her classes participated in PhysicsQuest in 2005, and again in 2006."The students enjoy solving the problems to get clues to the final answer," she said. "They enjoy the different experiments, and I am introduced to some new ones I have not earlier thought of. To be introduced to famous scientist and learn about less known sides of them is intriguing."

She has even gotten some extra use out of her 2005 PhysicsQuest kit. "After Benjamin's Franklin's secret message, I used materials from Albert's Einstein's hidden treasure to introduce the students to the connection between electricity and magnetism. It was great," she said.

Both Lampic and her students are already looking forward to next year's PhysicsQuest. "I have 5th graders coming up to me excited to be able to be part of PhysicsQuest next year." she said.

Lampic is making good use of the prizes–a colleague will use the skyrail kit for a physics project, and the gift card will help her equip her science room for next year.

APS public outreach coordinator Kendra Rand said, "Teachers love that PhysicsQuest kits are fun and motivating for their students and develop lab skills in line with the standards teachers are required to teach. Most of them look for the catch when we tell them the kits are free because they see the value in the product. I wish that APS members could see the teachers' reactions when we explain that the project is funded by the professional society for physicists. The teachers are grateful for the free materials, but I think what touches them even more is that the physics community recognizes that what they do in the classroom makes a difference."

PhysicsQuest first started in 2005. "PhysicsQuest was initially developed as a way for middle school students to celebrate the World Year of Physics 2005, but has since grown into a much larger project," said Rand.

With PhysicsQuest 2006 completed, kits are being developed for next year's activity, which centers on the young Marie Curie, who grew up in Warsaw at a time when women were not allowed to attend college there. Each of the experiments will give students a clue they need to help Marie and her classmates avoid being caught as they study in secret. The kit will include experiments on heat, energy, and temperature.

"Registration for the 2007 kit has been open for less than two weeks and we already have requests from over 700 teachers representing more than 3,000 classrooms of 6th-9th grade students," said Rand. "I think this is a testimony to the need within the middle school education community for accurate, fun physical science materials and to the difference that support and encouragement from the physics community can make."

Then You Diagonalize the Hamiltonian...

Photo by Brian Mosley

Carlos Meriles (left), Assistant Professor of Physics at CCNY, chats with Brian Baird (D-WA), Chairman of the Subcommittee on Research and Science Education of the House Science and Technology Committee. Meriles, who is the recipient of an NSF Career Award, testified before the subcommittee on March 29 as it considered priorities for the NSF. More information on the NSF hearings can be found at http://www.aip.org/fyi/2007/038.html .

M. Hildred Blewett Scholarship for Women Physicists

This scholarship has been established to enable women to return to physics research careers after having had to interrupt those careers for family reasons. The scholarship consists of an award of up to $45,000. The applicant must currently be a legal resident of the US or Canada. She must be currently in Canada or the US and must have an affiliation with a research-active educational institution or national lab. She must have completed work toward a PhD.

- Applications are due June 1, 2007. Announcement of the award is expected to be made by August 1, 2007.
- Details and online application can be found at http://www.aps.org/programs/women/scholarships/blewett/index.cfm

Contact: Sue Otwell in the APS office at blewett@aps.org

Estate Planning Session Held at March Meeting

An estate planning session was held at the March Meeting for meeting attendees and local APS members. John A. Warnick, a partner in the Denver office of Holme Roberts & Owen LLP, provided an overview of estate and wealth transfer planning. Topics included the importance of having a will, considerations when placing principle assets in joint names, gift tax exclusion opportunities, the importance of record-keeping and maintaining an up-to-date estate plan, and tips on how to choose an executor or trustee.

Handouts and brochures distributed at the session are available free of charge to APS members. Those who missed the session can get copies by contacting Darlene Logan at logan@aps.org or (301) 209-3224.

Correction:

In the Spring Prizes and Awards Insert in the March *APS News*, we erroneously referred to NIST as the National Institute of Science and Technology. The correct designation is the National Institute of Standards and Technology, reflecting its previous incarnation as the National Bureau of Standards (NBS). We thank Frank J. Lovas for pointing this out.

Call for Nominations

2008 APS Excellence in Education Award
Deadline: July 1, 2007

The award, which consists of $5000 and a certificate citing the achievements of the recipients, was established to recognize and honor a team or group of individuals (such as a collaboration), or exceptionally a single individual, who has exhibited a sustained commitment to excellence in physics education.

Five copies of the nomination packet should be submitted to the chair of the selection committee, Ken Krane, at the following address:

Department of Physics
Weniger Hall 301
Oregon State University
Corvallis, OR 97331-6507

Electronic submissions will not be accepted. The deadline for nominations is July 1, 2007. Further information may be obtained on the APS website at http://www.aps.org/programs/honors/awards/education.cfm or by contacting the chair of the selection committee at kranek@physics.oregonstate.edu.

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Climate Change is All About Energy

By Drew Shindell

Climate change is all about energy, a subject familiar to any physicist. Climate changes are driven by changes in the Earth's energy balance with space, either as the result of variations in the distribution or intensity of incoming solar radiation reaching the Earth, the fraction of that radiation that is reflected, or the emission of thermal radiation back to space. The greenhouse effect alters the latter, trapping outgoing terrestrial radiation. A reduction in emissions during recent decades at exactly the wavelengths where greenhouse gases (GHGs) absorb has been directly measured from space, so there is no question about this effect. Thus the relevant question is how sensitive is the Earth's climate to changes in the planetary energy balance?

Climate records from the distant past show that the Earth's climate is not immutable, but in fact is rather sensitive, especially at long timescales. Climate models are not given credence by the climate science community unless they exhibit sensitivity consistent with paleoclimate evidence. Given a sensitive climate, the increasing greenhouse effect should be causing our planet to warm up substantially. Modern measurements show that indeed the Earth as a whole has unquestionably warmed since the industrial revolution. However, climate records don't indicate causality on their own. Instead, a combination of climate data and understanding of the many potential drivers of energy changes is required to attribute cause and effect. Perhaps surprisingly, this is often easier to do in the distant past than in more recent times, as the potential sources of energy balance changes were far fewer prior to large-scale industrialization.

With this in mind, we can explore the relative roles of natural factors and human contributions to the warming since the industrial revolution. The strength of past solar variations is not well known (the timing is known, but not the amplitude), so while the global mean warming of the early 20th century can be at least partially reproduced in models by imposing increased solar output, this by itself tells us little. Climate variations over the past several centuries provide a more useful constraint, and indicate that given what we know about climate sensitivity, solar variations very likely were the dominant driver of long-term (multi-decadal and longer) climate variations during the last millennium. Models are able to match the hemispheric average temperature changes and large regional changes, such as the 17th and 18th century cooling in Europe and parts of North America that gave rise to the name 'Little Ice Age', best when we assume past variations in solar output were extremely small, only ~0.1-0.2%. Such small variations imply that solar forcing (here forcing means an "external" change affecting the climate system's energy balance) may have contributed to the warming of the early 20th century, but that it was too small to be the sole driver.

How about the more rapid warming of the last 40 years? Much of this time the sun has been monitored by satellites, and there has been no substantial increase in its output. Tellingly, solar increases would heat the stratosphere more than the surface, and observations show instead that the stratosphere has been cooling rapidly. This cooling is partially due to ozone depletion, but is also present at altitudes where there has been little ozone change, and stratospheric cooling is a well-known response to GHG increases. Thus the spatial structure of atmospheric temperature change doesn't fit the impact of solar increases. Instead, it bears the signature of increased GHGs. However, GHGs trap so much energy that were they the only important factor the planet would be warming even more rapidly than observed. It's clear that the enhancement of the greenhouse effect is being partially offset by aerosols (particulates), though details of these are poorly understood at present. Hence as for the early 20th century, the uncertainty in the forcing limits the value of comparing models with observations of global mean temperature trends. One can put in increasing GHGs and then offset the right amount with aerosols to reproduce the late 20th century global mean trend, but little is learned. A more convincing reason to trust the climate models is that when these are driven with increasing GHGs and other forcings, they are capturing more and more of the regional response of temperature and precipitation seen in observations, including cooling in certain regions and decreased rainfall in much of the subtropics.

Though aerosols have been offsetting a poorly quantified but certainly substantial portion of GHG forcing, they are unlikely to continue doing so. For one, GHG forcing is growing ever larger, so to offset a constant fraction would require ever larger aerosol emissions. Instead, aerosol emissions have been decreasing in the developed world as a result of air quality legislation, and are projected to do so in the developing world during the next 10-40 years. So while poor understanding of aerosols is sometimes cited as a reason to doubt warming projections, in fact the crucial point about aerosols is that their influence will almost certainly decrease, making the future prospects for warming even worse than one would estimate considering GHGs alone.

Thus climate science tells us several key things. Our planet is warming. The abundance of GHGs in the atmosphere is increasing due to human activities, and these are enhancing the greenhouse effect. Natural forcings appear not to have increased during recent decades, and only minimally during recent centuries. The Earth's climate sensitivity is constrained well enough from studying the Earth's history to know that the enhanced greenhouse effect will lead to substantial warming in the absence of offsetting effects, and future offsetting effects (primarily from aerosols) are likely to decrease. So global warming during the 20th century is very likely largely caused by the GHG increases, and warming in the future is very likely to increase. Most estimates find a warming of 2-2.5 C to constitute "Dangerous Anthropogenic Interference" with the climate, a term meaning a high likelihood of severely disruptive or even catastrophic climate changes which most of the world (including the US) has pledged to avoid. The Earth has warmed ~0.8 C already, and another ~0.6 C will take place as the planet adjusts to its current energy imbalance with space. Thus we have only another 0.6-1.1 C to go. It will be almost impossible to avoid this much additional warming without prompt, large-scale action worldwide.

What can we do? Again, it comes down mostly to energy. A whopping 80% of today's energy comes from fossil fuel burning, releasing huge quantities of CO_2 (the most important GHG forcing) into the atmosphere. While future projections of the world's population and economy are much less certain than even climate projections, most plausible futures show a large increase in energy usage, with double to triple current usage in 50-75 years. There are two clear options. First, energy can be generated from renewable sources that do not generate GHGs. Second, energy can be used more efficiently. Given the scale of the problem, it seems clear that both are imperative (along with efforts to halt and reverse deforestation, especially in the tropics, which also contributes substantially to atmospheric CO_2 increases).

Physics can contribute greatly to both strategies. Further improvement in renewable energy from wind, solar, and nuclear power should be near or at the top of national priorities. Instead, US energy research and development spending is today only 40% of what it was in 1980. A ban on construction of coal-fired power plants that do not design in the capacity to add carbon sequestration in the future is required for a serious effort to limit CO_2 emissions. While there are substantial economic costs to limiting coal burning and increasing use of renewable energy, at least in the short-term, there are significant potential economic gains as well and the technology is ready. In the EU, the expansion of wind energy since the 1990s has eliminated the need for nearly 50 new coal-fired plants, and renewable energy there is now a $20 billion industry. Physicists are also at the forefront of developing more efficient ways to use electricity, such as solid-state lighting. Electricity generation is currently only ~37% efficient, with nearly 2/3 lost in generation, transmission and distribution, leaving ample room for improvement. Distributed generation with capture and use of waste heat is a simple way to more than double the efficiency of electricity generation.

While science and engineering are crucial to solving our energy and climate problems, there are important roles for policy makers as well. California's history of independent regulations, an ironic positive legacy of horrendous air quality in the Los Angeles basin, provides telling examples. Primarily through mandating more efficient use of energy, California has held its per capita energy use roughly constant since the early 1970s (http://www.energy.ca.gov/efficiency/). During that same period, per capita energy use has gone up ~50% nationwide. California's advanced efficiency standards started in the 1970s for major appliances such as furnaces, air conditioners and refrigerators.

They have been so successful that energy use by these appliances has dropped 25, 40 and 75%, respectively. In contrast, the federal government only imposed standards in the early 1990s, when most of the efficiency gains had already been realized. Standards have also been gradually increased for buildings and utilities to use and generate energy efficiently. Contrary to the dire warnings sometimes heard from industry, the effect of standards has not been to destroy manufacturers by driving up the price of their product. Today's refrigerators that use one-quarter the energy of their 1970s predecessors and also cost roughly 60% less. Precedent shows that technology always seems to keep up with the regulations. Though industrial groups are currently suing California over its recent attempt to regulate emissions from automobiles more strictly, it's hard to accept that current regulations are adequate. Can some of the country's most talented scientists and engineers really not come up with a way to make more fuel efficient cars than we did in the 1970s (when current fuel efficiency standards were largely set)?

The benefits of having avoided the national increase of 50% in per capita energy use are tremendous. California emits 18 million tons less carbon per year, has greatly reduced emissions of smog precursors and particulate, both harmful to human health, and consumers save ~$12 billion in energy bills each year. This is money into the American economy instead of into foreign economies that seem almost inevitably to use their oil and gas income to maintain authoritarian regimes and often also to fund schools where fundamentalists are trained to hate the United States. Clearly using energy more efficiently is in America's best economic and national security interests in addition to environmental ones. Energy, economic and environmental success stories also exist in the developing world. For example, Brazil's sugarcane ethanol program for vehicles, begun in the 1970s in an effort to stop spending roughly half its earnings from exports on oil imports, has been enormously successful. Following decades of work, ethanol now sells for less than traditional gasoline without any subsidies and has saved Brazil over $50 billion in oil imports, far more than the program cost. At the same time it has created domestic jobs and substantially reduced the country's vulnerability to Middle Eastern oil crises. Efforts to wean the US from imported oil have, in contrast, been largely rhetorical.

Continued use of fossil fuels is inevitable for the immediate future, and potential solutions such as carbon sequestration and nuclear power require further study or remain controversial. There are no compelling reasons, however, that the US cannot rapidly become dramatically more energy efficient. Energy efficiency is not just a win-win situation, it's at least a "win to the fourth," improving air quality and human health, reducing climate disruptions, improving national security and boosting the American economy. Similarly, capture of methane released to the atmosphere from landfills, pipelines, mining and other sources reduces global warming and air pollution (methane is a precursor to ozone, a component of smog) and provides a valuable economic commodity (natural gas) that makes the long-term economics positive. Factoring in the costs of adverse health impacts of fine particles, reductions in black carbon soot also often lead to a net economic gain. Thus even without including the economic cost of climate change via a carbon tax or cap-and-trade system for CO_2, many global warming mitigation strategies make economic sense already for ancillary reasons. These are not put into practice due to systemic problems. For example, soot emitters do not pay the health costs, so lack an incentive to control emissions. Builders do not pay the occupant's energy bills, so are not motivated to strive for efficiency. Similarly, distributed power generation with use of waste heat saves energy, but utilities understandably aim to increase sales, not reduce them. Leadership is required to overcome these systemic problems and benefit society as a whole. Much is contentious in the US regarding solutions to global warming, but increasing energy efficiency and other "win-win" strategies should not be.

Drew Shindell is a senior climate scientist at NASA's Goddard Institute for Space Studies in New York. He is also a lecturer in the Department of Earth and Environmental Sciences at Columbia University.