APS NEWS
February 2003
Volume 12, No. 2
A Publication of The American Physical Society http://www.aps.org/apsnews

IN THIS ISSUE:
PHYSICS NEWS in 2002
Pages 4-9

Sreenivasan Is New ICTP Director

Katepalli Sreenivasan, a distinguished university professor of physics and mechanical engineering at the University of Maryland, College Park, has been appointed as the new director for the Abdus Salam International Center for Theoretical Physics (ICTP) in Trieste, Italy. He succeeds retiring director Miguel Virasoro, who has held the post since 1993.

Founded in 1964 by Pakistani physicist Abdus Salam, the ICTP's mission is to provide opportunities for physicists from developing countries to interact with those from developed countries, while encouraging them to remain in their home countries. Its contributions to the international physics enterprise include visiting programs for international scholars, scientific workshops and conferences, remedial courses in science education, and distribution to developing countries of scientific journals, conference proceedings, and electronic databases. The Center houses a small but excellent permanent scientific staff in high energy physics, mathematics, condensed matter and statistical physics, and physics of weather and climate.

Known as "Sreeni" to friends and colleagues, Sreenivasan received his education in India, first at the University of Bangalore and then at the Indian Institute of Science in Bangalore, where he earned a doctorate in aerospace engineering in 1975. After two years of postdoctoral study in Sydney and Newcastle, Australia, he came to the U.S. as a researcher at Johns Hopkins University. Later he became the Harold W. Cheel professor of mechanical engineering and professor of physics, applied physics and mathematics at Yale University. He moved to Maryland in January 2001, where he directs the university's Institute for Physical Science and Technology. His primary fields of research are fluid dynamics and turbulence, and he has published extensively on these and other related subjects.

"Sreeni is a world renowned experimental physicist with an appreciation for theory and has a deep understanding of both the frontier research enterprise and the potential of intellectual talent in developing countries," said Irving Lerch, APS director of international scientific affairs of Sreenivasan's appointment. It comes at a particularly critical time in the Center's 30-year history. Originally the operation of the institute was the responsibility of the International Atomic Energy Association (IAEA), with additional support provided by UNESCO and the Italian government. Since 1992, governing authority has been transferred to UNESCO, and according to Lerch, with Virasoro's retirement, UNESCO is considering the tightening of the ICTP management. The implications of the new policy remain to be seen, but as the new director, Sreenivasan will play an important role in the future of the Center.

Furthermore, the Italian gov-

See SREENIVASAN *on page 2*

Photo credit: Laleña Lancaster

Incoming ICTP Director Katepalli Sreenivasan (seated, center) meets at APS headquarters with Executive Officer of APS and Secretary-General of IUPAP Judy Franz (left); Chair of the APS Committee on International Scientific Affairs Peter Barnes (right); and APS Director of International Affairs Irving Lerch (standing).

Questioned Papers in Physical Review Journals Retracted

APS journals are printing retractions of six papers as a result of the Lucent Technologies/Bell Labs inquiry into misconduct by Jan Hendrik Schön. Two of the papers, published in *Physical Review B*, were implicated in the Lucent investigation chaired by Malcolm Beasley of Stanford University. They were retracted with the agreement of all authors.

Four additional papers, published in *Physical Review B* and *Physical Review Letters*, but not studied by the Lucent investigation, were retracted with the agreement of all authors except Schön. Two papers, one that included Schön as a coauthor and the other with Schön as the sole author, remain in the literature after the authors indicated that they do not wish to retract them.

According to APS Editor-in-Chief Martin Blume, in view of the seriousness of the issue, APS felt it prudent to contact Schön and all of his living coauthors (one is deceased) about articles in APS journals, although only two of the eight articles were explicitly discussed in the Lucent report. Information from these coauthor indicates scientific concerns for all the retracted papers. "Given the notoriety of this case, we felt that people ought to know the status of all of the articles," Blume says.

All coauthors felt the papers should be retracted. Schön declined to join in this statement except with regard to the two papers mentioned in the Lucent report. Given the preponderance of evidence from the Lucent report and the opinions of Schön's coauthor, the APS decided it was in the best interests of the community to report the fact that these articles are being retracted by most of the authors, while also reporting Schön's contrary view.

Retractions will appear in upcoming print issues of the journals and online versions will have notations to indicate the retractions. The online tables of contents and abstracts of the papers will include a message with links to the full text retractions.

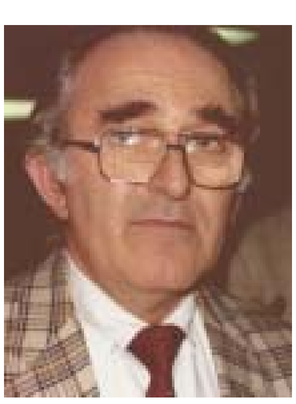
The editors of the *Physical Review* journals have chosen to leave the retracted papers available online as part of the research record, just as they remain in archived print copies of the journal. However, online versions will appear with clear statements of retraction and all papers affected will be accompanied by links to the retractions. These notations will appear so that researchers will be able to see them regardless of how they navigate to the versions of the papers online. "We do not want to tamper with the archive of published papers," says Blume.

See RETRACTED *on page 3*

APS Member Gives Minority Scholarship Fund a Boost

The APS Corporate Minority Scholarship received a financial boost last year with the establishment of a trust fund yielding about $5,500 annually. Aleksandar Svager, a professor emeritus at Central State University (CSU) in Ohio and long-standing APS member, had always planned to establish a trust in his name upon his death, but financial advisors at the Greene Community Foundation (also in Ohio) convinced him he could do so before then. Besides, "My doctor assures me I will live," he laughs.

Widowed three and a half years ago, Svager has also established a scholarship fund in mathematics through the Dayton Foundation in honor of his late wife Chrysa, who was the first female African-American to receive a PhD in math. The first three scholarships were awarded last year. The couple worked together to encourage more African-American students to major in math and physics since they first met in 1964 at CSU, an historically black university where Chrysa was a math professor. They married on commencement day in 1968.



Aleksandar Svager

Svager discovered his gift for teaching early on while still a student in Sarajevo, Yugoslavia, tutoring those who were struggling with math and science. He spent a little over two years at the Nuclear Institute of Zagreb, teaching at the university there, and also taught at the University of Sarajevo before coming to the U.S. in 1960 through the Institute for International Education. He earned his master's degree in physics from Texas Christian University. Eager to stay in the U.S. when the Yugoslavian government asked him to return, but unwilling to place his family and friends back home in danger by requesting political asylum, Svager did the next best thing: he took a faculty position with CSU and devoted himself to the teaching he loved, becoming chair of the physics department a year later.

The most rewarding aspect of

See SVAGER *on page 3*

For Some APS Prizes and Awards Competition Cuts Across All Fields'

Many APS prizes and awards are given for contributions to specific areas of physics research, but a few are open to all fields of physics across the board. "While these include some of the most prestigious prizes that the APS awards, they are usually not publicized by individual units and so it's probably a good idea to remind our members about them in case they know of someone who deserves to be nominated" said Alan Chodos, APS Associate Executive Officer.

Leading this list is the **George E. Valley Prize**, which, with a stipend of $20,000, carries the largest monetary award of any APS prize. Founded with a bequest from the estate of George E. Valley, Jr., it is given every other year, and will be awarded for the second time in 2003. Its purpose is "to recognize one individual,

See AWARDS on page 10

Highlights

10 **Physics And Technology Forefronts**
Protein Folding, HIV and Drug Design.

12 **The Back Page:**
Meg Urry Speeding up the Long Slow Path to Change

Physicists Honored at Southeastern Section Meeting

From left to right: Paul Cottle, Myron McCay, and Raymond Flannery. Three members of the Southeastern Section of the American Physical Society were presented awards for outstanding contributions to physics in the region at the annual meeting held October 31 – November 2, 2002, at Auburn University. Professor Paul Cottle, Florida State University, received the George B. Pegram Award: "For his outstanding university teaching, and his untiring efforts and innovative programs to help K-12 science teachers." Professor Emeritus Myron McCay, University of Tennessee at Chattanooga received the Francis G. Slack Award: "For his contributions to the Southeastern Section of the American Physical Society, and physics education in the South." Professor Raymond Flannery, Georgia Institute of Technology, received the Jesse W. Beams Award: "For his pioneering, seminal, influential and enduring contributions to Atomic and Molecular Collision Physics."

SREENIVASAN *from page 1*

ernment is by far the largest financial supporter of the ICTP, and Lerch believes that "there is a real danger that the Center will be absorbed into the Italian institutional system and lose its original purpose." Sreenivasan, however, does not anticipate such an occurrence, since thus far the ICTP has been left autonomous. "Everyone recognizes that the Center is truly scientific in nature," he says. "It's worked very well thus far and there is no reason to change it now." His focus will be on improvements in management, a renewed commitment to the Center's original mission, and achieving greater reknown for the quality of the scientific research done at the Center.

Sreenivasan also takes the helm in a radically changed international climate in the aftermath of the terrorist attacks of September 11, 2001, with much harsher restrictions on travel and more difficulty in acquiring visas to travel to other countries, even for scientific exchange. However, Sreenivasan, a self-described optimist at heart, also believes that the tragedy has had a positive impact in terms of fostering the notion of an international community. "I think people have a greater understanding about why it is important to engage the rest of the world in some constructive way in order to be at peace ourselves," he said. "We recognize better now that events occurring on the other side of the world can affect us here in the U.S."

In fact, it was the chance to make a difference internationally and give something back to the world physics community that attracted Sreenivasan to the post, despite the personal sacrifices associated with accepting it. It means not only a substantial reduction in salary, but also the necessity of leaving his wife, a psychiatrist, and teenaged son in New Haven, Connecticut, at least until his son completes high school. "I am from one such developing country and I was received in the U.S. science community very well; I spent many years on the receiving end," he said. "I have done my best to create opportunities for others in turn, but this is an opportunity where the scope is substantially larger."

"I have always viewed physics as a unifying feature among the many divisions we have as human beings, bringing together physicists of different cultures, origin, background and economic progress," he said. "And perhaps many will act as ambassadors for this grand notion of a unified world." His belief in, and commitment to, the unity of physics is even reflected in his title: in addition to being director, he will also be the Abdus Salam professor. "I thought it would be nice to have an Indian with the title of a Pakistani professorship," he said. "I hope it is a symbol I can carry forward in my work with the ICTP."

This Month in Physics History

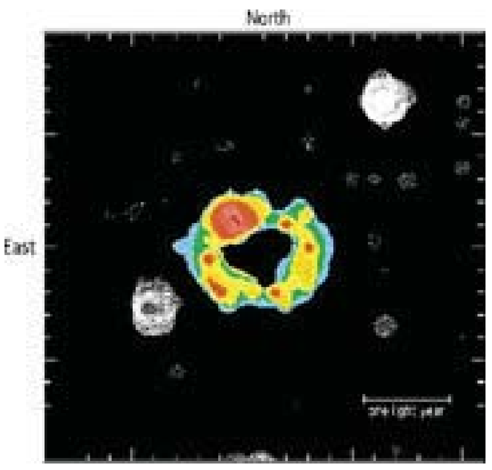
February 1987: Discovery of Supernova 1987A

On February 23, 1987, Canadian astronomer Ian Shelton (then with the University of Toronto) was engaged in what he thought was merely routine work at the Las Campanas Observatory in Chile, taking a telescopic photo of a small galaxy 167,000 light-years from Earth called the Large Magellanic Cloud. But when he developed the photographic plate, he noticed an extremely bright star that he had not seen in previous observations of the same area: a star of about the fifth magnitude. He realized that it was not a new star, but an aging massive star that had blown apart in a supernova explosion.

Data taken by a small telescope aboard the International Ultraviolet Explorer (IUE) satellite helped astronomers identify the exploding star's location as Sanduleak -69° 202, the former site of a blue supergiant about 20 times the mass of the sun. They named the exploding star Supernova 1987A. Astronomers believe the star swelled up to become a red supergiant, puffed away some of its mass, and then contracted and reheated to become a blue supergiant. In less than a second, the star's core collapsed, and a wave of neutrinos heated the inner core to 10 billion degrees. The process triggered a shock wave that ripped the star apart, propelling a burst of neutrinos into space.

Supernova 1987A is the closest supernova to have exploded in modern times, and the brightest since Johannes Kepler observed a supernova in 1604 in the Milky Way Galaxy; it is also the first supernova visible to the naked eye since 1885. In addition, research over the last 15 years has yielded a wealth of new observational data that has provided astronomers with unprecedented insight into the processes that govern stellar bodies.

By May 1987, the IUE team had discovered an abundance of chemical elements in the supernova debris, indicating that the progenitor star had already passed through the red giant phase, and verifying the original theory. By July, a Japanese satellite and West German telescope detected x-rays emanating from the debris. And from August to November, several other research missions detected high-energy gamma rays, typically released in the decay of radioactive elements formed in nuclear reactions at the core of a dying star. The data confirmed a widely held theory that supernovas produce the heavy chemical elements that make up most of the matter on Earth.



The nebula of SuperNova 1987A photograhed in 2002.

Two years later, optical observations in La Silla, Chile, showed a bright ring around the Supernova, an observation that was confirmed a year later by the Faint Object Camera aboard the newly deployed Hubble Space Telescope. Since its discovery, the remnant from Supernova 1987A has been expanding. Its rings are thought to be parts of shells of gas ejected by the star long before the explosion. In May 1997, Hubble's imaging spectrograph produced a detailed ultraviolet image of the inner ring, identifying specific gases such as oxygen, nitrogen, hydrogen and sulfur, which astronomers hope will help them assemble a picture of how the ring was created.

Radio waves were detected for two weeks after the supernova was first observed, but in 1990, scientists at the Australia Telescope National Facility detected rapidly brightening radio emissions, which they traced to an area that lies between the ring and the glowing debris of the supernova at its center, where the most rapidly moving debris is crashing into gas. Two years later, the ROSAT satellite detected rapidly brightening x-rays from the supernova, coming from the same collision area as the radio waves.

In May 1994, Hubble revealed two additional loops of glowing gas. In January 1997, it showed two blobs of debris in the Supernova's center racing away from each other at nearly 6 million mph. Later that year, astronomers made the first measurements of the fast-moving gas ejected by the supernova explosion—gas that had been invisible until Hubble's imaging spectrograph enabled scientists to observe it in ultraviolet light.

The collisions were predicted by theory, and expected to occur sometime between 1995 and 2010, as the ring absorbed the full force of the crash. While the radiation from the original explosion traveled out at the speed of light, material from the star itself was ejected at a much lower speed, and was only now catching up and colliding with material blown out some 20,000 years earlier by the star. The collision caused the gases in the ring to glow as they heated to millions of degrees, compressed by a blast wave estimated to be moving at 40 million mph.

As recently as February 2000, Supernova 1987A was still yielding surprising discoveries on stellar processes. New images taken by Hubble revealed four bright new knots of heated gas in an area that had been fading slowly for a decade. This was significant because the hot spots were not confined to a single location, but distributed around the circumstellar ring, indicating that a large fraction of the ejected material was finally colliding with the entire ring, marking the beginning of the formation of a Supernova remnant. Astronomers hope that the light from the collisions will illuminate matter surrounding the Supernova that until then had been invisible, providing useful information on the true structure of the gas around the Supernova, and enabling them to determine how it might have gotten there.

APS NEWS

Series II, Vol. 12, No. 2
February 2003

Coden: ANWSEN ISSN: 1058-8132

Editor .... Alan Chodos
Associate Editor .... Jennifer Ouellette
Special Publications Manager .... Elizabeth Buchan-Higgins
Design and Production .... Stephanie Jankowski
Forefronts Editor .... Neville Connell
Proofreader .... Edward Lee

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 20749-3844, 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.

Subscription orders, renewals and address changes should be addressed as follows: For APS Members—Membership Department, American Physical Society, One Physics Ellipse, College Park, MD 20740-3844, membership@aps.org.

For Nonmembers—Circulation and Fulfillment Division, American Institute of Physics, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502. Allow at least 6 weeks advance notice. For address changes, please send both the old and new addresses, and, if possible, include a mailing label from a recent issue. Requests from subscribers for missing issues will be honored without charge only if received within 6 months of the issue's actual date of publication. Periodical Postage Paid at College Park, MD and at additional mailing offices. Postmaster: Send address changes to *APS News*, Membership Department, American Physical Society, One Physics Ellipse, College Park, MD 20740-3844.

NUMBER SEVEN

Scaling Theory of Localization: Absence of Quantum Diffusion in Two Dimensions

(E. Abrahams, P. W. Anderson, D. C. Licciardello, and T. V. Ramakrishnan, Phys. Rev. Lett. 42 (1979) 673), 2446 citations

This is the fourth in a series of articles by James Riordon. The first article appeared in the November 2002 issue. The articles will be archived under "Special Features" on the *APS News* online web site.

The seventh paper in our list of the ten most cited Physical Review Letters *revolutionized understanding of the electrical properties of materials in certain, important regimes.* APS News *interviewed three of the paper's authors, and some of their thoughts are reprinted below.*

Elihu Abrahams is the Bernard Serin Professor of Physics (emeritus) at Rutgers, Nobel Laureate Philip Anderson is the Joseph Henry Professor of Physics (emeritus) at Princeton, and T. V. "Rama" Ramakrishnan is a newly elected Fellow of the Royal Society and a physics professor at the Indian Institute of Science in Bangalore. Donald Licciardello left Princeton shortly after the publication of the *Scaling Theory of Localization* PRL to found Princeton Telecom, and was not available for an interview.

APS News: What are the important findings in your 1979 PRL?

Abrahams: There were two significant results from our paper. One is the new conclusion that in a two-dimensional, disordered electronic system (i.e. defects are present) where the electrons do not interact with each other (or the interaction, for some reason, can be neglected) the ground state, which is the state at zero temperature, is always insulating. Thus, there are no true metallic states in two-dimensions. The other important conclusion is that in dimensions greater than two, where you could have a metal-insulator transition by changing some parameter (such as the degree of disorder), the transition is continuous. This means that, as you pass from metal to insulator at zero temperature, the conductivity goes continuously to zero, rather than jumping from some minimum value to zero.

APS News: Why has the paper acquired so many citations?

Ramakrishnan: The initial attention was I think due to the fact that we made experimentally testable, unusual predictions based on a new quantum, many-body, interference process; one which explored the process of localization, *i.e.* the nature of transition from a metal to insulator. At that time (1978-79), the question of the nature of this transition and its experimental manifestations was beginning to attract a lot of attention, since it represents a total change in the nature of electronic states (from extended to localized) not as a result of binding to a strong enough attractive potential as in one-electron quantum mechanics, but as a consequence of increasing disorder.

Abrahams: In recent years, the experimental discovery of what appear to be metallic states at zero temperature in 2-D systems has resulted in many experimental and theoretical papers which also reference our earlier work.

APS News: What led you to study this particular problem?

Anderson: It was partly a lecture I gave in an advanced course which set me thinking, plus a lunch table conversation with Rama and Abrahams, where Rama recalled some puzzling old work which we generalized. We were all aware of Sir Neville Mott's idea [regarding resistivity and disorder] and experimental data confirming it, and Licciardello had written a paper with Thouless which kind of foreshadowed scaling.

Ramakrishnan: . . . Anderson had shown, in a famous paper published in 1957, that if the medium in which the electron moves is sufficiently disordered, the electronic state is spatially localized and is not extended throughout the system (free electron).The system is then an insulator. For small disorder, one intuitively feels that the system is a metal with a small residual resistivity. What is the nature of the transition from metal to insulator as disorder is increased? There was a very significant conjecture with considerable experimental support, due to Sir Neville Mott which went as follows: as disorder increases, the residual resistivity continues to increase to a maximum value (which he estimated) and then, for a slightly larger disorder, one has an insulator with an infinite resistivity (at T=0). This focused attention on the fact that none of the theories of localization at that time calculated a physically measured quantity such as resistivity; they concentrated on whether the state was localized or not, *e.g.* by trying to calculate the localization length, or asking whether an electron in the random medium diffused away or not.

APS News: Were you surprised by the theoretical results of the work?

Ramakrishnan: Yes, very much so. We had uncovered a new quantum mechanical process of interference between paths for the electron starting and ending at the same point, diffusing through the random medium, but in opposite directions. This is the localizing process which increases the amplitude for an electron to come back where it started. It leads to a nonclassical scale-dependent resistivity and is behind the unexpected result that there are no metals in two dimensions, at absolute zero.

Anderson: No, it seemed to fit right in with what we knew or guessed.

APS News: How has your career been affected by being the author of such a highly cited paper? Has it limited your options as a researcher? Has it expanded them?

Abrahams: Briefly—it was good for the career, hasn't limited research options and expanded them somewhat.

Ramakrishnan: It was a wonderful experience, especially after the discovery of the localizing process, to take part in the creative interaction between theory and experiment, and to realize the variety of new phenomena which 'emerge' from a new idea.

Anderson: This is my nth highly cited paper so it couldn't make that much difference. It was a little important to me because it bolstered my self-confidence at that particular time. I had read things about how the Nobel prize would destroy my productivity, which I now know is hogwash—it depends on what you want to do, and I wanted to go on producing physics. But I also wrote a highly cited paper, more important than this one, in 1977 (TAP, or Thouless-Anderson-Palmer), and continued to do important physics until now.

APS News: Is there anything else you'd like to say?

Anderson: I was delighted with the prominence of this paper because El Abrahams had been important in following up my original localization work and hadn't been recognized for it, and just for alphabetical reasons we put him first—he, Rama and I contributed pretty equally. Another nice thing was that it was followed by a spate of work worldwide which was very cooperative and collegial, with everyone cooperating with everyone else - Russians, Japanese, Germans, Americans, Indians and others. It was a marvelous contrast to what has happened with other discoveries.

Top 10 (±2) Physics Pick-Up Lines (in randomized order)

by the University of Wisconsin-River Falls Society of Physics Students

1). You x Me = Love

2). I want to sum the forces to your heart!

3). What's a nice girl/guy like you doing in a n-dimensional space like this?

4). Let's take a ride down the Quantum Tunnel of Love!

5). The reduced χ^2 of your beauty is zero compared to the theoretical model!

6). I'm trapped in the potential well of your gaze!

7). $\delta_{if} = \begin{cases} \text{love; } i = \text{me}, j = \text{you} \\ 0 : i = \text{me}, j \neq \text{you} \end{cases}$

8). Your love is at my fundamental frequency!

9). In the integrated circuit of our relationship, there are no resistors, only capacitors!

10). Your B aligns my spin toward you, babe!

11). The size of my love creates a gravitational field that attracts only you!

12). I want you to diagonalize my inertia tensor!

RETRACTED *from page 1*

"It will say in red 'retraction.' It's like a scarlet letter."

The retractions also link to the full text of the Beasley report, which Lucent has given the APS permission to mirror at a permanent web address associated with the journals. It is available at http://publish.aps.org/reports/. In the past, Schön has denied committing misconduct, saying only that he made "mistakes."

A full list of the *Physical Review* papers in question can be found in the online version of this article at http://www.aps.org/apsnews .

SVAGER *from page 1*

teaching for Svager is the opportunity to make a real difference in students' lives. Although CSU's physics department is small, it has produced around 40 physics majors since Svager first joined the faculty, all but five of them African-American. Of those 40, 30 went on to receive master's degrees in various fields, and five eventually earned PhDs, three in physics.

But Svager's favorite story concerns a young female student he tutored while still at Texas Christian University, the daughter of his next-door neighbors, who was majoring in math. She ended up earning a double degree in math and physics, ultimately earning a PhD in physics. On the day she graduated, she presented Svager with two gifts: a set of Cross pens, and a signed form to drop her physics course. It turned out she had been planning to drop physics when Svager offered to tutor her, "but because of me, she decided to double major," he said. "So I knew I could make a difference." And he continues to do so today with his support of the Society's Minority Scholarship program.

Physics News in 2002

A Supplement to APS News

Edited by Phillip F. Schewe and Ben P. Stein
Media & Government Relations Division, American Institute of Physics

TABLE OF CONTENTS

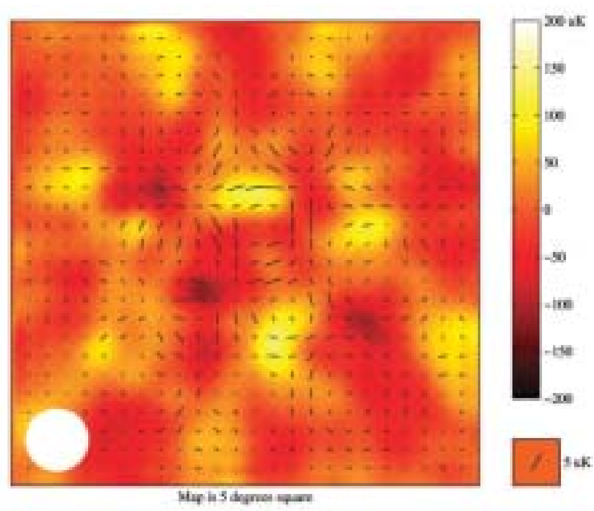
Astrophysics 4
Atomic, Molecular, and Optical Physics 4
Biological Physics 5
Condensed Matter, Materials Physics 6
Particle, Nuclear, and Plasma Physics 7
Other Physics Highlights 8
Highlights of Science Policy and Budget 9

INTRODUCTION

Physics News in 2002 is a summary of physics highlights compiled from items appearing in the weekly newsletter *Physics News Update* of the American Institute of Physics (AIP). Many of the entries appearing here were also published in *Physics Today* magazine, where they were edited further by Stephen Benka. Readers should keep in mind that because of the way *Physics News Update* itself is prepared (short items aimed primarily at science journalists) and because of limited space in *Physics News in 2002*, some fields of physics research might be under-represented in this compendium. Readers can get a much wider view of the year's top physics research by going to the *Physics News Update* website at http://www.aip.org/physnews/update or APS's *Physical Review Focus* website at http://focus.aps.org/. The material appearing under the headline "Highlights of Science Policy and Budget Developments in 2002" on page 9 is a compendium from the electronic news service FYI produced by the Media and Government Relations Division of the AIP. See http://www.aip.org/enews/fyi/ .

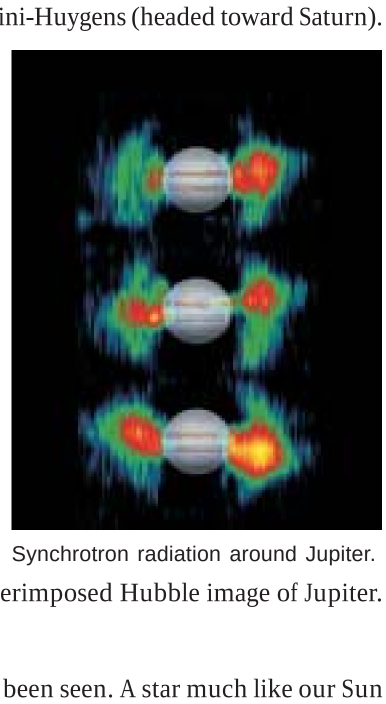
ASTROPHYSICS

POLARIZATION IN THE COSMIC MICROWAVE BACKGROUND has been measured. The most fundamental properties of the CMB — which can reveal conditions in the universe when it was only about 400,000 years old—are its frequency spectrum and its angular power spectra of both temperature and polarization fluctuations. According to the modern theory of cosmology, the CMB microwaves received an orientation (polarization) just before the seething plasma that pervaded the cosmos in that early era finally became a neutral, transparent gas. Until now, the low level of polarization had allowed that quantity to escape detection. Using the Degree Angular Scale Interferometer detector situated at the South Pole, a group from the University of Chicago and the University of California, Berkeley, has acquired and analyzed enough high-quality data to actually see the CMB polarization. The observed value is consistent with predictions and thus strongly validates the underlying theory. (J. Kovac *et al.*, preprint available at http://arXiv. org/abs/astro_ph/0209478.)

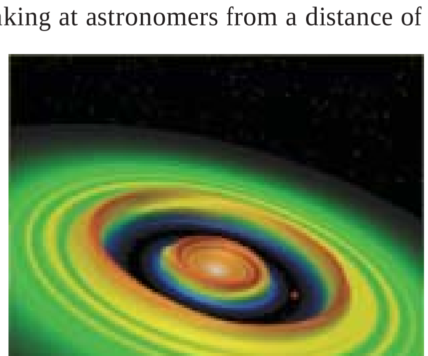


An image of the intensity and polarization of the cosmic microwave background radiation made with the Degree Angular Scale Interferometer (DASI) telescope. The small temperature variations of the cosmic microwave background are shown in false color, with yellow hot and red cold. (Courtesy DASI collaboration.)

JUPITER'S MAGNETOSPHERE has been simultaneously sampled by two spacecraft, Galileo (already on patrol in the Jupiter system) and Cassini-Huygens (headed toward Saturn). Just as Cassini was approaching Jupiter in January 2001, other Earthbound observatories, including radio telescopes and the Hubble (optical) and Chandra (x-ray) satellites, were turned to the giant planet. The Sun also cooperated: Three interplanetary shock waves in the solar wind swept by. The two spacecraft caught Jupiter's magnetosphere in the act of being compressed. That compression produced strong electric fields and therefore particle accelerations, which brightened Jupiter's auroras. Internal magnetospheric dynamics caused other observed auroral brightenings and a wind of neutral atoms—formed from ions spewed by Io's volcanic eruptions—sent outward against the incoming solar wind. Such energetic neutral atoms had not been directly observed before. The flyby also provided the first opportunity to observe electrons above 50 MeV trapped in Jupiter's radiation belts. Shown here is the synchrotron radiation from those electrons, with a superimposed Hubble image of Jupiter. (Seven articles in *Nature* **415**, 985, 2002.)


Synchrotron radiation around Jupiter.

A YOUNG EVOLVING PLANETARY SYSTEM has been seen. A star much like our Sun when it was only 3 million years old has been winking at astronomers from a distance of about 2400 light years for the past five years. Every 48.36 days, the star suddenly dims to a small percentage of its normal brightness for about 18 days. The duration and depth of these periodic occultations, discovered by William Herbst and his colleagues at Wesleyan University in Connecticut, had not been seen before. Eighteen days is much too long for occultation by a lone planet in a 48-day orbit. The observations' most likely explanation, put forth by Herbst at a meeting at the Carnegie Institution of Washington in June 2002, is that a collection of dust grains, rocks, and perhaps asteroids is strung out in a clumpy arc of an orbiting circumstellar disk, with a larger object like a protoplanet shepherding the material. Now, with a worldwide collaboration watching the star continually, the Wesleyan group has found evidence that the orbital period is, in fact, 96.72 days: The star is being occulted by two separate clumpy regions on opposite sides of the disk. Theoretical models indicate that a single shepherding object could account for both clumps. The 97-day period indicates that the ringlike disk is about as far away from the star as Mercury is from the Sun. The collaboration has also seen the system changing slightly on a scale of months and years, thus tantalizing astronomers with the prospect of viewing planetary evolution in real time. (W. Herbst *et al.*, http://www.astro.wesleyan.edu/kh15d/)


An artist's rendition illustrates a possible configuration of a young evolving planetary system (Courtesy, Geoffrey Bryden, JPL.)

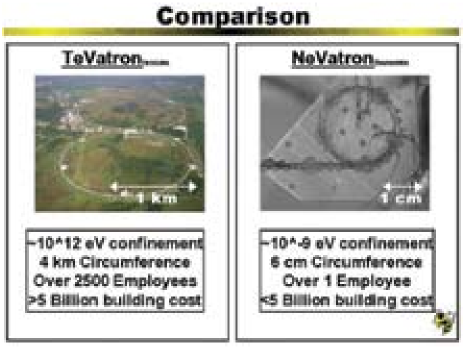
SPIRAL ARMS, COSMIC RAYS, AND ICE AGES. Most cosmic rays (CRs) are thought to originate in supernovae, and most supernovae occur in the wake of galactic spiral density waves. Nir Shaviv of the University of Toronto and Jerusalem's Hebrew University has developed a new CR diffusion model that includes the presence of arms. Not surprisingly, he found that the CR flux at Earth would vary with time and be correlated with our Solar System's passage through galactic spiral arms as we circumnavigate the Milky Way. He then looked at a historical record of CR flux, in the form of 42 age-dated iron meteorites whose exposures to CRs could be determined. He found a periodicity of 143 million years in the CR flux, which he attributes to passages through spiral arms. On the assumption that CRs ionize Earth's lower atmosphere and can thus influence climate, Shaviv next looked at the geologic record for ice ages and found "a compelling correlation" of both period and phase between CR flux and glaciation epochs during the past billion years. Between 1 and 2 billion years ago, there is no evidence for any ice age, consistent with a slowed star-formation rate during that period of our galaxy's history. Shaviv says that the weakest link in his analysis is the uncertainties in the glaciological record. (N. J. Shaviv, *Phys. Rev. Lett.* **89**, 051102, 2002.)

NEW COSMOLOGICAL UPPER LIMIT ON NEUTRINO MASS. Recent neutrino results imply that one or more of the three neutrino flavors (electron, muon, and tau neutrinos) have some mass (see *Physics Today*, July 2002, page 13). Considering the number of neutrinos loose in the universe, even a small mass means they will have significantly influenced the development of galaxies. Various physics experiments have established an upper limit of 3 eV for the electron neutrino and whopping upper limits in the MeV range for the muon and tau neutrinos. Now, a worldwide collaboration of astronomers has looked at the distribution of 250,000 galaxies in the 2 Degree Field Galaxy Redshift Survey and measured large-scale structure statistics in the form of a power spectrum. They compared the data with calculated power spectra using a model that included baryons, cold dark matter, massive neutrinos (hot dark matter), and a cosmological constant. The model had a few reasonable assumptions—for example, that all three types of neutrinos drop out of thermal equilibrium at the same temperature and that the spectrum of primordial fluctuations from which galaxies evolved is scale-independent—and an appropriate treatment of previously measured cosmological parameters. The group then arrived at two big conclusions: Neutrinos can account for no more than 13% of the matter in the universe, and the sum of all three neutrino masses is no more than 2.2 eV. Group members Oystein Elgaroy and Ofer Lahav say that this is the best upper limit for neutrino mass derived with relatively conservative assumptions on cosmological parameters. (Elgaroy *et al.*, *Phys. Rev. Lett.* **89**, 061301, 2002.)

QUAOAR is the provisional name for a large, newly discovered planet like inhabitant of our solar system. First spotted on 4 June 2002, Quaoar (pronounced KWAH-o-wahr) lives in the Kuiper Belt debris zone beyond Neptune's orbit. Its diameter of 1250 km is about half that of Pluto, and its distance of 42 astronomical units from Earth is far beyond Pluto's current distance of about 30 AU. (One AU is the mean distance of Earth from the Sun, about 150 million kilometers.) Caltech scientists announced the finding in October at the meeting of the division for planetary sciences of the American Astronomical Society, held in Birmingham, Alabama. (Abstract 9.04, *Bull. AAS* **34**(3), 2002. Also see http://www. gps.caltech.edu/~chad/quaoar.)

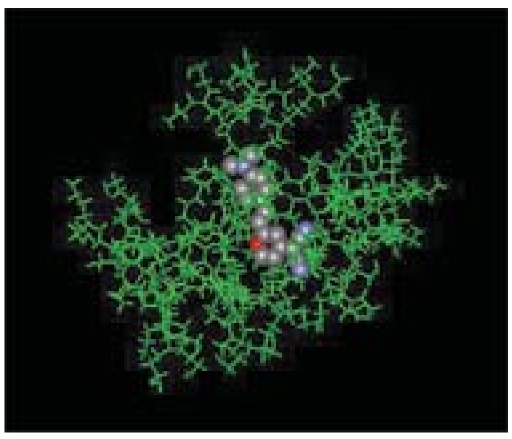
ATOMIC, MOLECULAR, AND OPTICAL PHYSICS

STORAGE RING FOR NEUTRAL ATOMS. Generally, a storage ring not only stores charged particles but also defines their energy and trajectory; particles with the wrong energy simply fly away from their magnetically guided route. Neutral atoms don't have a net charge for magnets to act on, but they can have a net magnetic dipole moment. If the atom moves slowly enough, its dipole is sufficient for magnetic guidance, and several such neutral atom guides have already been built. Physicists at Georgia Tech have now built a ring only 2 cm across, consisting of two concentric current-carrying wires, separated by 840 mm. They also built a wire "funnel" to transfer neutral rubidium atoms from a magneto-optic trap to the ring, where the atoms moved at only 85 cm/s, corresponding to kinetic energies of about 100 neV. The researchers thus dubbed their device the "Nevatron." The image shows an atom cloud after having completed two full circuits between the two ring wires. So far, swarms of 1 million atoms have made as many as 10 circuits around the ring. The physicists are extending the work to include ring-based atom interferometry and cold-beam generation. (J. A. Sauer, M. D. Barrett, M. S. Chapman, *Phys. Rev. Lett.* **87**, 270401, 2001.)



A tongue-in-cheek comparison of the TeVatron and the NeVatron (Courtesy Michael Chapman, Georgia Tech.)

A DENDRIMER LASER has been demonstrated. A conventional dye laser uses fluorescing dye molecules as the active medium. When excited with an external laser, the molecules emit a range of wavelengths that are then tuned by the dye-laser cavity. In most dye lasers, the dye concentration cannot go above a millimole/liter without quenching the fluorescence. Now, scientists at the Communications Research Laboratory in Japan and PRESTO Japan Science and Technology Corp have achieved lasing with a dye concentration of 9 mmol/l by encapsulating the dye molecules at the heart of hyperstructured, tree-shaped polymers called dendrimers. As the dye concentration increased within the new dendritic high-gain medium, the laser output also increased while the lasing threshold decreased. Furthermore, the resultant spectral linewidth was only 0.1 nm. The researchers are now working to incorporate their dendrimers into solid-state waveguides, optical fibers, and photonic crystals. (S. Yokoyama, A. Otomo, S. Mashiko, *Appl. Phys. Lett.* **80**, 7, 2002.)



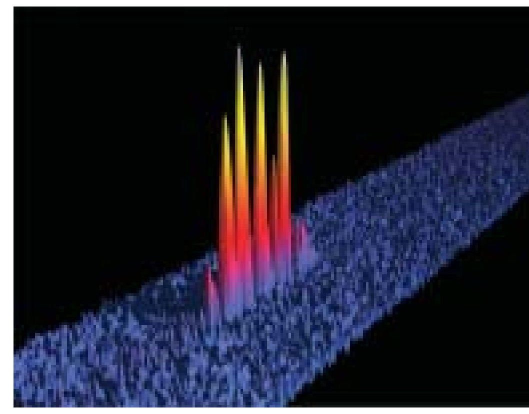
A large dendrimer polymer molecule (green) with a dye molecule lodged at its center. (Courtesy S. Yokoyama et al.)

LIGHT SLOWED AND STORED IN A SOLID. The group velocity of light—the speed at which the wave pulse propagates—can be considerably lowered, even to zero, in a medium having an index of refraction that changes dramatically with wavelength. The energy and information in the original light pulse can be stored, without any heating, in the form of coherent spin excitations in the atoms of the medium. Last year, two different experiments stopped and stored light in a vapor sample (see *Physics Today*, March 2001, page 17). Now the feat has been carried out in a 3-mm-thick crystal-yttrium silicate doped with atoms of the rare earth praseodymium-already in common use for high-density optical data storage. The experiment was carried out at MIT and at the Air Force Research Laboratory in Hanscom, Massachusetts. The researchers foresee many applications in areas such as quantum computing, ultrasensitive magnetometry, and acousto-optics. (A. V. Turukhin *et al.*, *Phys. Rev. Lett.* **88**, 023602, 2001.)

NONLINEAR LASER WITH ULTRALOW THRESHOLD. Physicists at Caltech coupled a 70-micron silica sphere to an optical fiber, which enabled light to race around near the surface of the sphere in a "whispering gallery" mode. Whispering modes have been produced before, for example, in microdroplets, but practical applications seemed remote. The light buildup in these modes is characterized by a parameter Q, referred to as the quality factor; for the microsphere, Q exceeded a hundred million. The light can build up to such an extent that nonlinear interactions take place and engender coherent light emission. The result is a Raman laser, which is tunable and can be used as a pump for other lasers. Typically, Raman lasers need a highpower input to work at all. But the Caltech result achieved lasing with only tens of microwatts of input power—1000 times less than other Raman lasers and in a much smaller package—although the output was only picowatts. The nonlinear properties of light in the silica microspheres offer new avenues of exploring quantum optics. (S. M. Spillane *et al.*, *Nature* **415**, 621, 2002.)

ALL-OPTICAL TRAPPING OF A DEGENERATE FERMI GAS has been demonstrated. First created in a magnetic trap (see *Physics Today*, October 1999, page 17), a degenerate Fermi gas consists of fermionic atoms—those with an odd total number of protons, neutrons, and electrons—sufficiently dense and cold that only the lowest trap energy levels are occupied. An all-optical trap has previously been used to confine a Bose-Einstein condensate (see *Physics Today*, July 2001, page 20 and September 2001, page 79). Now, using a stable, high-power CO_2 laser, physicists at Duke University have created a kind of "optical bowl" for lithium-6 atoms: Slowly lowering the bowl's rim permitted the hottest atoms to evaporate. The researchers then adiabatically recompressed the trap to its full depth, which tightly confined the remaining degenerate gas. In this way, an equal mixture of lithium atoms in spin-up and spin-down states was captured, a feat not possible in magnetic traps. According to the Duke researchers, such equal two-state mixtures are potentially ideal for forming neutrally charged, quasibound pairs of atoms in Fermi gases—something the researchers hope to observe soon. Several groups are pursuing such an atomic-gas analog of superconductivity in different ways. (S. R. Granade *et al.*, *Phys. Rev. Lett.* **88**, 120405, 2002.)

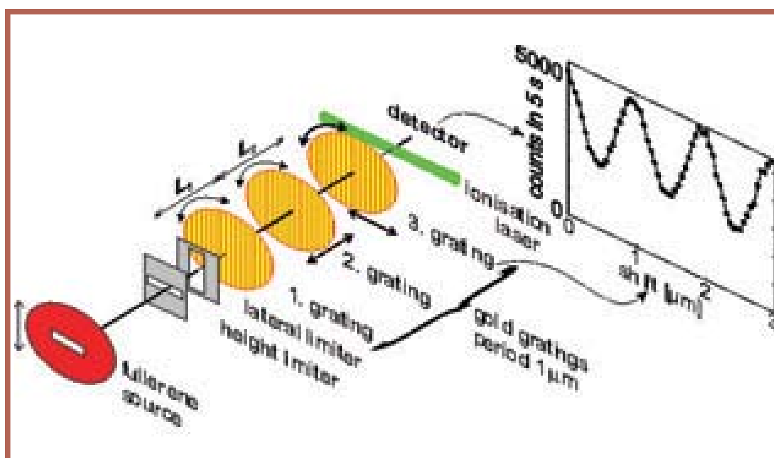
BRIGHT SOLITONS IN A BOSE-EINSTEIN CONDENSATE. A soliton is a localized wave that, because of nonlinear effects, can travel for long distances without spreading out or losing its original shape. Solitons can occur in all kinds of waves, including sound and light. In fact, solitons are regularly used in telecommunications in optical fibers. Essentially a macroscopic matter wave, a BEC can also form solitons. Usually, however, a BEC quickly spreads after it is released from the trap in which it was created. Now, groups at Rice University in Houston and at the Ecole Normale Supérieure in Paris have been able to form BEC solitons with lithium-7 atoms. Both groups used a tunable magnetic field to adjust the interatomic interactions from repulsive-necessary to form a stable condensate-to weakly attractive. The attractive interactions provided a self-focusing nonlinearity that exactly compensated for wavepacket dispersion. After releasing the atoms into a 1D potential, both groups observed solitons that propagated without changing shape for more than a millimeter—a truly macroscopic distance. The Rice experimenters formed a train of up to 10 individual solitons, which appeared to repel each other as they oscillated in a weakly harmonic potential. The Paris group set up an open waveguide and accelerated a single soliton. Matter-wave solitons may prove useful for eventual technological applications of BECs, such as for gyroscopes for ultraprecise navigation, very accurate atomic clocks, or other devices that use atom interferometry. (K. E. Strecker *et al.*, *Nature* **417**, 150, 2002; L. Khaykovich *et al.*, Science **296**, 1290, 2002.)



Bright Solitons, composed of Bose-Einstein Condensates of lithium-7, have been observed in a single beam optical trap (Courtesy Randy Hulet and colleagues, Rice University.)

SONOLUMINESCENCE ENERGY IS MAINLY CHEMICAL, according to a new set of experiments at the University of Illinois. Yuri Didenko and Kenneth Suslick quantified the energy consumption during sonoluminescence, the conversion of ultrasonic waves into picosecond light pulses via rapid oscillations of bubbles in a liquid. They found that, during the compression phase, a bubble's interior gets hot enough to dissociate many gas molecules and initiate a furious session of chemical reactions. The researchers carefully monitored the reactant products—mostly nitrite ions (NO_2^-), hydroxyl radicals (OH), and light—of a single bubble of air in a bath of water subjected to ultrasound. They found that about 100 times more energy goes into chemical reactions than into light. Their experimental conditions were very different from those used for the recent claim of "sonofusion" (see *Physics Today*, April 2002, page 16), and thus their results may not apply to that claim. However, Dan Shapira and Michael Saltmarsh of Oak Ridge National Laboratory did duplicate the sonofusion conditions. They showed that the earlier coincidence data can be accounted for by random coincidences; they also placed an upper limit on the relevant neutron emission that is 10^4 less than that implied by the earlier claim. (Y. T. Didenko, K. S. Suslick, *Nature* **418**, 394, 2002. D. Shapira, M. Saltmarsh, *Phys. Rev. Lett.* **89**, 104302 , 2002.)

A MATTER-WAVE INTERFEROMETER FOR LARGE MOLECULES. A matter-wave interferometer for large molecules has been devised and demonstrated for the first time. For many years scientists have studied the proposition that things we normally think of as particles, such as electrons, should also have wave properties. Indeed studies of beams of electrons, neutrons, even whole atoms, have confirmed that particles can be viewed as a series of traveling waves which diffracted when they pass through a grating or through slits. These waves could even interfere with ach other, resulting in characteristic patterns captured by particle detectors. In this way, in 1999 Anton Zeilinger and his colleagues at the University of Vienna demonstrated the wave nature of carbon-60 molecules by diffracting them (in their wave manifestation) from a grating. Now the same group, using a full interferometer consisting of three gratings with wider grating spacings and a more efficient detector setup, observe a sharp interference pattern. Moreover, because the beam of particles used, carbon-70 molecules at a temperature of 900 K, are themselves in an excited state (undergoing 3 rotational and 204 vibrational modes of internal motion), it should be possible to study the way in which an atom wave, or in this case a macromolecular wave, becomes decoherent (that is, loses its wavelike character) Because of thermal motions and other interactions with its environment. Thus this type of interferometer experiment will be useful in studying the borderland between the quantum and classical worlds. The researchers are aiming to study the wave properties of even larger composite objects, mid-sized proteins. (Brezger *et al.*, *Physical Review Letters* **88**, 100404, 2002).



A matter-wave interferometer for large molecules (Courtesy University of Vienna)

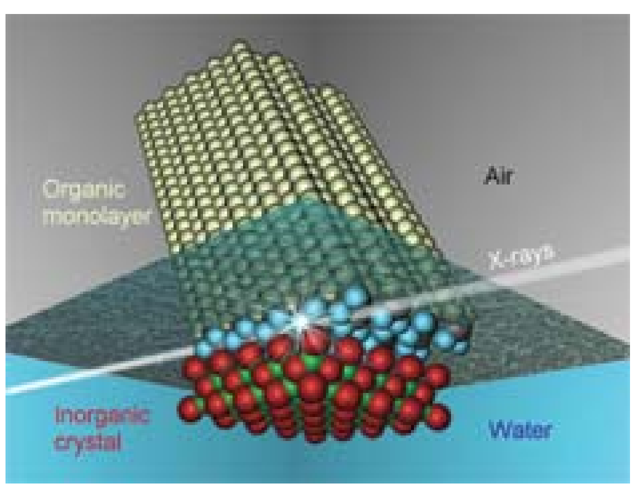
BIOLOGICAL PHYSICS

ELECTRICAL BIOSENSORS FOR INDIVIDUAL LIVING CELLS were described at the March 2002 meeting of the American Physical Society. Cells are complex networks of interacting molecules, and are usually studied with optical techniques. Electrical measurements, however, can provide complementary information. Toward that end, Lydia Sohn of Princeton University described several new biosensors. With one, she measured the amount of DNA in a single living cell passed through a small fluid chamber between two metal electrodes. The cell changed the system's capacitance in a way that reflected the amount of the cell's negatively charged DNA but not its other ions. Sohn reported that the technique can identify the stage of a cell's development (since cells can contain different amounts of DNA at different stages) and can potentially distinguish cancerous cells from healthy ones. Sohn also described a biosensor that can detect small amounts of a specific protein in live *E. coli* cells. The eventual goal of Sohn's lab is to take inventory of a living cell's protein contents—something that cannot be done with current protein assay techniques, which require the destruction of cells. (More information at http://www.aps.org/meet/MAR02/baps/vpr/layf7-003.html.)

NOISE CAN IMPROVE HUMAN BALANCE CONTROL, to the point that it may enable elderly subjects to steady themselves as well as their young counterparts, researchers in New England have demonstrated. Noise, in this case, refers to random mechanical vibrations applied to the feet. In physics, noise denotes any random or seemingly useless fluctuation. Static on a radio station, peripheral conversations in a crowded room, and flashing neon lights along a busy thoroughfare all tend to obscure or distract one from receiving the desired information. But more and more studies in a wide variety of systems—global climate models, electronic circuits and sensory neurons, to name a few—have shown that certain levels of noise can actually enhance the detection and transmission of weak signals, through a mechanism known as stochastic resonance (SR). Here the authors show that postural sway, the slight movements exhibited by the body when it is erect, can be significantly reduced for both young and elderly individuals. The authors achieved this by randomly applying subtle mechanical vibrations, just below the threshold of sensory perception, under the subjects' feet. The random vibrations likely act to enhance the sensation of pressure on the soles of the feet. The authors further demonstrate a trend in elderly subjects towards reducing their postural sway to the level of young subjects, suggesting that noise may be a "fountain of youth" for human balance. These results indicate that the random vibrations may ameliorate age-related impairments in balance control. Noise may provide similar beneficial effects in individuals with marked sensory deficits, such as patients who have suffered a stroke or a disorder in the peripheral nervous system. In the future, the authors speculate, noise-based devices, such as randomly vibrating shoe inserts, may enable people to overcome functional difficulties due to age- or disease-related sensory loss (Priplata *et al.*, *Physical Review Letters*, **89**, 238101, 2002). This paper comes on the heels of another recent finding, that the random hand motions generated by noise in the human nervous system make it possible for people to balance a stick on a finger (Cabrera and Milton, *Physical Review Letters* **89**, 158702, 2002).

VISCOSITY OF TWO-DIMENSIONAL SUSPENSIONS is similar to that in three dimensions. Many technologically and biologically important interfaces are actually monolayers composed of two coexisting phases: solid like crystals of the molecules floating in a sea of liquid like molecules. Researchers at the University of California, Santa Barbara, measured the viscous drag on a magnetic needle in monolayers of human lung surfactant lipids. They found that if the relative fraction of the layer's area that contained crystals was low, the viscosity was also low and the monolayer spread easily. As the crystals' coverage increased, so did the viscosity until, at a critical fraction of the total area, the monolayer abruptly became rigid. Moreover, the behavior held for a wide range of surface pressures, temperatures, and monolayer compositions and was the same as that for a 3D dispersion of hard spheres in a solvent with long-range repulsive interactions. The scientists believe their work could lead to better replacement surfactants—for example, for premature infants with respiratory distress syndrome. Human lung surfactant has an important role in replacing the blood's carbon dioxide with oxygen. It helps keep the lungs' tiny air sacs properly inflated by controlling their surface tension. (J. Ding *et al.*, *Phys. Rev. Lett.* **88**, 168102, 2002.)

A STRETCH-FIT TEMPLATE FOR FILMS of organic and inorganic molecules. Many biological processes, such as bone formation, require hard inorganic materials to grow on a soft macromolecular substrate, although precisely how the two mesh has been something of a mystery. To examine that issue, physicists at Northwestern University floated a two-dimensional array of a fatty acid (a Langmuir monolayer) on a supersaturated solution of barium fluoride (BaF_2), which then crystallized at the interface. Separately, the two lattices are incommensurate. Using x-ray diffraction, the researchers observed that both lattices adapted in order to register with each other. The lattice of the BaF_2 thin film contracted by a few percent and the organic lattice expanded by tilting the molecules. The result was that the facial areas of the unit cells fell into a commensurate ratio of 1.5. BaF_2 is not a biologically important mineral, but Pulak Dutta says he and his fellow group members expect to look directly at biomineralization in an upcoming phase of their work. (J. Kmetko *et al.*, Phys. Rev. Lett. **89**, 186102, 2002.)



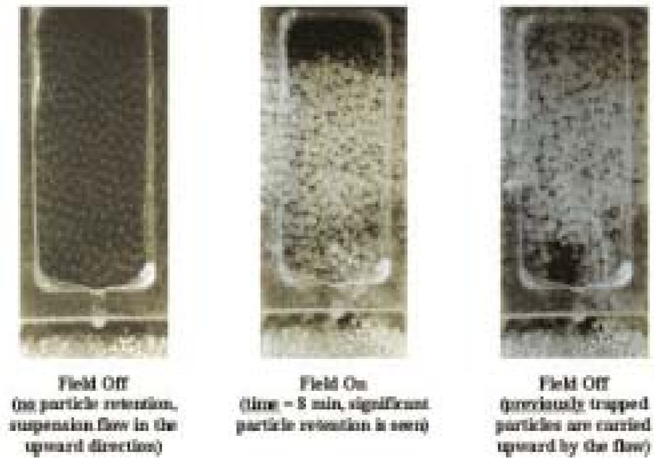
X rays are used to reveal, in detail for the first time, how an inorganic crystal (barium fluoride) can grow, in registry, upon an organic material (a fatty acid). (Courtesy, Jan Kmetko, Northwestern Univ.).

CONDENSED MATTER/MATERIALS PHYSICS

SUPERCONDUCTIVITY IS REDUCED as a system becomes more one-dimensional. Moving through very thin passages, Cooper pairs of electrons, which constitute the supercurrent, are sensitive to quantum effects not noticeable in larger wires. For example, quantum phase slips-fluctuations in which the superconducting wavefunction spontaneously tunnels from one state to another-occur well below the critical temperature. The tunneling produces a momentary voltage, and therefore a nonzero electrical resistance, even if the temperature could somehow be reduced to absolute zero. Armed with progressively thinner wires—down to 10 nm across—of molybdenum-germanium deposited onto carbon nanotubes, Michael Tinkham and his colleagues at Harvard University have definitively shown that resistance goes up as the wire diameter goes down. The quantum resistance effect only becomes noticeable for wires less than about 30 nm across. By going to lower temperatures, says Tinkham, one can eliminate resistivity arising from thermal fluctuations, but not from quantum fluctuations. (C. N. Lau *et al.*, *Phys. Rev. Lett.* **87**, 217003, 2001.)

INSLULATOR-TO-METAL within a picosecond. A group from the University of California, San Diego, and the University of Quebec studied a 200-nm thick film of vanadium oxide (VO_2). They fired a 50-fs laser pulse at the sample, causing what they believe to be two phase transitions: a structural one (the unit cell size increases a bit), monitored with short x-ray pulses; and an electrical one (insulator-to-metal), monitored by short pulses of visible light. The simultaneous, ultrafast measurement of more than 1 degree of freedom showed that both transitions happened essentially all at once. Therefore, the experiment still did not settle an old question in condensed matter physics: Which comes first, the structural change in the sample or the electrical change? Because the crystalline reordering occurs in a few hundred femtoseconds and is reversible, and because x rays scatter differently from the two contrasting crystalline forms, it might be possible to use this whole process as an ultrafast "Bragg switch" to divert subpicosecond portions of a longer x-ray wavetrain. (A. Cavalleri *et al.*, *Phys. Rev. Lett.* **87**, 237401, 2001.)

SOUND WAVES MAKE FILTERS FINER. Generally, the performance of filters that remove particulates from fluids is limited by their pore sizes: A filter with large pores isn't likely to catch many tiny particles. By contrast, a filter with tiny pores will trap small particles but inhibit fluid flow. Now, Donald Feke (Case Western Reserve University) has trapped particles up to a hundred times smaller than the nominal pore size by applying a low-power acoustic signal to the filter. The sound field within a porous material creates patterns of standing waves associated with the pores. Rather than wending their way through the filter, particles headed for the focal points either form intricate, stable filaments or gather into groups that orbit in regions of stability for as long as the signal persists. Such an acoustically aided filter offers little resistance to the fluid that flows through it, yet collects particles as efficiently as a much finer filter does. And once the filter has done its job, the trapped particles can be released with the flip of a switch that cuts off the signal. Feke presented his work at the 73rd annual Society of Rheology meeting in Bethesda, Maryland.



Acoustic filter: when an acoustic signal is turned on, tiny particles are trapped by a complex pattern of standing sound waves (Courtesy CWRU)

LIGHT-ACTIVATED PLASTIC MAGNET. Photoinduced magnetism is of considerable interest in data storage applications. Over the past six years, the phenomenon has been seen, generated, and studied in several different materials. Now, scientists at Ohio State University and the University of Utah have produced light-induced magnetization in an organic-based material, tetracyanoethylene (TCNE), contained within a manganese compound. When the material was exposed to blue light from an argon laser, its magnetization increased by as much as 50%. The material was magnetic at temperatures below 75 K and retained its magnetism for days, perhaps through the formation of a metastable state in a distorted lattice. The magnetism could be partially undone by green light, and completely undone by heat. The researchers believe that the light can be selectively targeted to domains as small as, or smaller than, the wavelength of the light itself, thus possibly enabling information storage. Magneto-optic effects are currently used only to retrieve information. The new process promises to offer both reading and writing capabilities. The benefits of plastic electronic components made of plastic include flexibility, low cost, and tunability. (D. A. Pejakovic *et al.*, *Phys. Rev. Lett.* **88**, 057202, 2002.)

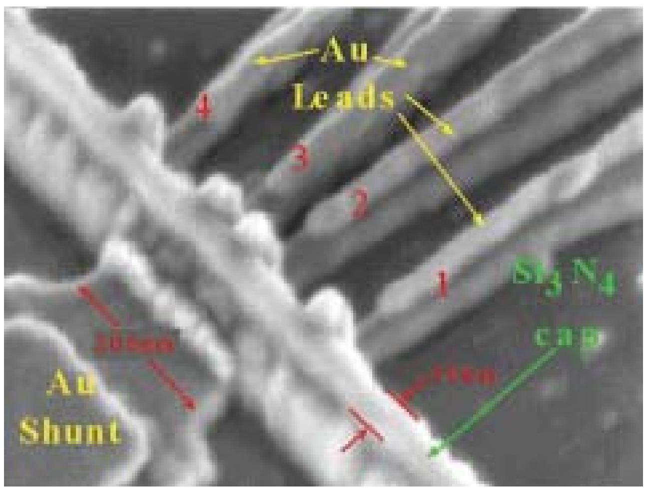
RAPID-RESPONSE HYDROGELS, water-swelled polymers that quickly change their properties when triggered by the right stimulus, have been created. A hydrogel is a 3D cagelike polymer that is relatively sluggish in responding to the application or removal of stress, light, or a change in acidity. Using a novel design based on artificial protein polymers, a collaboration of scientists from the University of California, Santa Barbara, and the University of Delaware has now developed a hydrogel that can recover quickly after the removal of mechanical stress. The novel hydrogel contains two chemical building blocks: one that is highly charged and hydrophilic and another that is hydrophobic and has a special shape that causes the polymers to link and form a porous hydrogel at very low concentrations in solution. After the gels were shaken vigorously to break down their structure, they recovered 80% of their strength in a matter of seconds, even at 90°C. The rapid response and highly porous nature of the new hydrogel potentially opens up new biotechnological uses for the compound. Possibilities include an organic scaffolding to hold regenerating tissue within the body and a drug-delivery capsule to hold large proteins and release them when given the right stimulus. (A. P. Nowak *et al.*, *Nature* **417**, 424, 2002.)

MICROTESLA NUCLEAR MAGNETIC RESONANCE has been demonstrated. In conventional NMR, a several-tesla magnetic field is used to orient atomic nuclei in the sample. The polarized nuclei can resonantly absorb a burst of radio waves, and precess around the imposed field. The spectral "chemical shift" information from reemitted radio waves is then used to identify molecules. NMR also lies at the heart of magnetic resonance imaging (MRI). Now, a team of scientists led by John Clarke and Alexander Pines (Lawrence Berkeley National Laboratory and the University of California, Berkeley) have exploited an often overlooked fact: For a homogeneous field, the NMR linewidth scales linearly with the field strength. Thus, a 1000-fold reduction in field strength produces a line both narrower and taller by that same factor. The researchers placed a small liquid sample of methanol and phosphoric acid in a polarizing field of only 1 mT and a much weaker orthogonal measuring field of 5 mT (Earth's field is roughly 50 mT). The group then turned off the polarizing field and used a SQUID to detect not chemical shift but "J-coupling," which can measure an atom's chemical environment as well as its identity. In that way, they not only identified protons and phosphorous—31, but saw the signature—a doublet split by 10.4 Hz—of the covalent bonds in trimethyl phosphate. These techniques open the possibility for "pure J" spectroscopy and perhaps could form the basis of inexpensive MRI machines. (R. McDermott *et al.*, *Science* **295**, 2247, 2002.)

A SINGLE-PHOTON LIGHT-EMITTING DIODE has been created. At the May 2002 CLEO/QELS meeting in Long Beach, California, scientists from Toshiba Research Europe Ltd described a nanometer-scale indium arsenide quantum dot integrated into a conventional gallium arsenide LED structure. Using a pulse of electric current, the researchers could induce a single electron and a single hole to recombine in the dot, thus generating a single photon. Because the exciton's lifetime was 1.0 ns and the equipment had subnanosecond time resolution, the physicists could verify that photons were emitted singly. The researchers believe this is the first electrically driven single-photon source. Such single-particle-emitting sources could offer a potentially inexpensive and convenient component for quantum cryptography and other applications. (Paper QTuG1 at the meeting; see also Z.Yuan *et al.*, *Science* **295**, 102, 2002.)

A NANOSCALE NONMAGNETIC READ-HEAD SENSOR, based on extraordinary magnetoresistance (EMR), has been developed. Today's state-of-the-art magnetic recording delivers about 15 gigabits per square inch of recording medium. To achieve that result, the read head uses magnetic metals in a layered structure with either the giant magnetoresistance (GMR) or tunneling magnetoresistance (TMR) effect to convert the field orientation (up or down) of tiny magnetic domains into changes in electrical resistance. Both effects make use of electrons' spin and are subject to magnetic noise. By contrast, EMR makes use of electrons' orbital degrees of freedom; the magnetic fields deflect a current from a conducting shunt attached to the semiconductor and thereby produce resistance changes. A group led by

Stuart Solin of NEC Research Institute in Princeton, New Jersey, has now used nonmagnetic, silicon-doped indium antimonide to build a mesoscopic read head (see the scanning electron micrograph) that operates on the EMR principle. According to Solin, GMR and TMR will ultimately have a noise-limited areal density of about 150 Gb/in^2, whereas EMR could reach 1 Tb/in^2 and has a fast enough response time to utilize that density. The researchers fabricated their 116-Gb/in^2 device using a multistep electron-beam lithography process that required excruciating accuracy: Features needed to be aligned to within 10 nm. Although free of magnetic-noise limitations, the device needs to sense magnetic fields that are 10 times stronger than those sensed with current technologies, which could limit its practical application for the time being. (S. A. Solin *et al.*, *Appl. Phys. Lett.* **80**, 4012, 2002.)



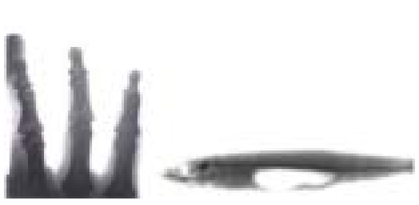
A nanoscale, nonmagnetic read_head sensor, based on extraordinary magnetoresistance (EMR). (Courtesy Solin et al..)

SINGLE-SPIN TRANSISTOR. Spintronics is a relatively new field in which an electron's spin, not just its charge, is exploited in devices and circuits. Physicists at the Institute for Microstructural Science in Ottawa, Canada, have connected a quantum dot to spin-polarized leads in an external magnetic field. They emptied the dot of conduction electrons and then added them back one at a time. The researchers found that the total spin of the electrons depended both on the number of electrons in the dot and on the applied magnetic field. With fewer than about 20 electrons in the dot, an even number of spins paired off in singlet states with zero net spin, whereas an odd number had a net spin corresponding to the unpaired electron. Above the critical number, however, the additional electrons all had the same spin polarization. Furthermore, the single-spin, singlet, and polarized phases of the dot each allowed different currents to flow through the dot. The physicists controlled the spin state of the dot either by adding electrons or by tuning the magnetic field, and thus produced a prototype single-spin transistor. The group believes their work may play a role in future solid-state forms of quantum information. (M. Ciorga *et al.*, *Phys. Rev. Lett.* **88**, 256804, 2002.)

BALLISTIC MAGNETORESISTANCE (BMR) is yet another way in which spin orientation can modify electrical resistance in a circuit. The sensitive part of the circuit might consist of sandwiches of alternating magnetic and nonmagnetic layers (giant magnetoresistance and tunnel magnetoresistance) or might have no magnetic materials at all. In BMR, the sensor is a quantum point contact of ferromagnetic atoms between two wires. The contact is narrower than the typical scattering path length for electrons, which therefore move ballistically in straight trajectories. Any scattering an electron suffers will be due only to magnetic effects. If the electrons in the circuit are spin polarized then they will scatter more or less (with greater or lesser resistance) at the contact, depending on the contact's magnetization state and on the faint force exerted by any nearby tiny magnetic storage domain. In a new BMR experiment conducted at SUNY Buffalo, Harsh Chopra and Susan Hua found a remarkably large resistance change in nickel nanocontacts at room temperature. For example, they saw a change in resistance of more than a factor of 30 (from 8 to 260 ohms) in an applied magnetic field of less than 0.016 T (160 gauss). The researchers say that they can reliably reproduce the BMR effect in many samples. (H. D. Chopra, S. Z. Hua, *Phys. Rev. B* **66**, 020403(R), 2002.)

THE ROLE OF THE NANOSCALE IN ARTIFICIAL LEAVES has been elucidated. Several semiconductor materials are known to catalyze the removal of excess airborne carbon dioxide in the presence of light and organic molecules, just like real leaves. For example, bulk surfaces of cadmium sulfide and zinc sulfide can photocatalytically fix CO_2 into an organic molecule. Cadmium selenide, however, can only accomplish that task in its Cd-rich nanocrystalline form. Three physicists at Oak Ridge National Laboratory and Vanderbilt University believe they have now found out why. In a series of parameter-free, first-principles calculations, they found that CO_2 is adsorbed only at Se vacancies and then becomes negatively charged and, potentially, more reactive. The CO_2 does not react on the surface; it needs to yank the extra electron out of the semiconductor, desorb, and become incorporated into another molecule elsewhere. For this scenario to occur, the extra electron must first be excited into the semiconductor's conduction band, for example by shining light on it. Still, the energy cost is too high for the charged CO_2 to desorb from bulk CdSe. Enter the nanoscale. As a nanocrystal's size decreases, its energy gap increases. Thus, electrons can flow freely to desorbing CO_2 molecules if the CdSe crystal is small enough. As a bonus, the theorists found that n-doping with indium might allow CO_2 fixation to take place without the need for light. (L. J. Wang, S. J. Pennycook, S. T. Pantelides, *Phys. Rev. Lett.* **89**, 075506, 2002.)

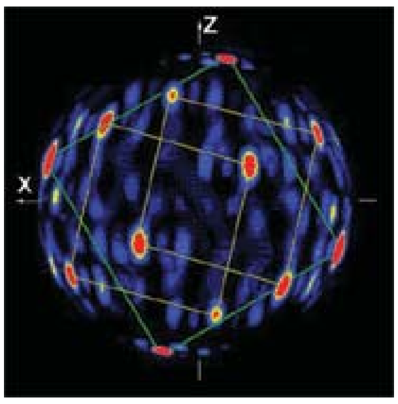
NANOTUBE DIAGNOSTIC X RAYS. The design of the x-ray tubes used in many medical and dental offices is essentially unchanged from a hundred years ago. A metal filament, the cathode, emits electrons when heated to more than 1000° C. The electrons are accelerated across a vacuum tube into a target, where they generate x rays. Now, a team of physicists and doctors at the University of North Carolina at Chapel Hill and the nearby firm of Applied Nanotechnologies Inc has created an x-ray tube using a room-temperature array of carbon nanotubes in a field-emission triode. They demonstrated a sufficiently large and stable current for practical medical imaging, as shown here by the x ray of a fish. According to the researchers, the device can be much smaller, is expected to last longer, and can produce a more focused x-ray beam than the hot-cathode design. In addition, the response time is sharper and the pulse shape and timing can be programmed, all of which help in the tracking of moving objects. (G. Z. Yue *et al.*, *Appl. Phys. Lett.* **81**, 355, 2002.)



Pictures of a hand and a fish taken with a carbon-nanotube source of x rays. (Courtesy UNC/Applied Technologies)

A SOLID-STATE CATHODE RAY TUBE has been developed by scientists at the Tokyo University of Agriculture and Technology. The CRT used in most television sets and computer monitors consists of a bulky box with a gun that shoots electrons (cathode rays) from a hot cathode through a vacuum toward a phosphor screen. The new vacuumless solid-state equivalent makes use of nanocrystalline porous silicon, in which electrons subjected to an electric field are accelerated to several eV by a multiple-tunneling cascade through the interfacial barriers between nanocrystallites. The energetic electrons then ballistically hit a luminescent organic film deposited on the silicon, resulting in uniform planar light emission. Nobuyoshi Koshida argues that the device, unlike other flat-panel luminescent display candidates, has all of the desirable technological features: It consumes little power, is silicon-based, produces a sharp picture, is scalable to large areas, responds quickly, is inexpensive because of its simple design, and can easily incorporate the three primary colors. (Y. Nakajima, A. Kojima, N. Koshida, *Appl. Phys. Lett.* **81**, 2472, 2002.)

ATOMIC-RESOLUTION NEUTRON HOLOGRAPHY. To obtain a holographic image, one must record the interference of two coherent waves emitted by the same source. One wave must reach a detector directly while the other first scatters off of the object to be imaged. Holography using lasers has been familiar for decades, but better resolution has been achieved in recent years with electron and x-ray holography (see *Physics Today*, April 2001, page 21). Neutrons, however, because they only interact with nuclei, may offer a more versatile alternative. Last year, a group led by Laszlo Cser of the Central Research Institute for Physics in Budapest, Hungary, proposed two ways to use neutrons for holography. Soon thereafter, a group in Canada realized one of those methods-the inside-source method-using hydrogen, a strong neutron scatterer, to act as a point source of neutron waves within a sample. Now the second, the inside-detector method, has been demonstrated by Cser and his colleagues. The group placed a single crystal of lead, in which they replaced a few Pb atoms with cadmium, into a neutron beam. Because Cd absorbs neutrons 106 times more readily than does Pb, the Cd acts as an internal neutron detector. The number of absorptions depends on the total neutron wave field at the Cd, including the interference between the directly arriving and previously scattered neutron waves. After absorbing a neutron, the new Cd isotope emits gamma radiation as it drops to the ground state, and those photons provide the data for the hologram. The physicists not only found the correct lattice parameter (4.93 angstroms) but also determined the sample's orientation in the neutron beam. Cser believes that holography with polarized neutron beams will be valuable for studying the structure of magnetic materials. (L. Cser *et al.*, *Phys. Rev. Lett.* **89**, 175504, 2002.)



Neutron hologram of a lead crystal. The spots represent the positions of 12 lead atoms forming the first neighbors of a cadmium nucleus, as displayed on a sphere of radius .35 nm. (Courtesy Central Research Institute for Physics, Budapest)

PARTICLE, NUCLEAR, PLASMA, BEAMS PHYSICS

SOLAR NEUTRINO PROBLEM CLOSED. The solar neutrino problem has been closed and the ability of neutrinos to change from one type, or "flavor," to another established directly for the first time by the efforts of the Sudbury Neutrino Observatory (SNO) collaboration. This finding gives physicists new confidence that they understand how energy is produced in the sun's core and that neutrinos are just as quirky as we thought. The benevolent sunlight we receive on Earth has its origin in the sun's central fusion furnace, whence the light must fight its way outwards in a series of scatterings that takes, on average, hundreds of thousands of years. Solar neutrinos, setting out from the same place, flee unhindered, thus providing the most unadulterated proxy of activity at the core. Measurements dating back to the 1960's of this neutrino flux were puzzling: only a fraction of the expected number arrived at detectors on Earth. Suspicion naturally fell on the experiments and on the standard solar model (SSM) used to calculate the flux.

Soon, however, the neutrinos themselves were implicated. If on their journey to Earth some of the neutrinos (basically, solar reactions produce electron-neutrinos) had changed into muonor tauneutrinos, then terrestrial detectors designed only to spot electron neutrinos (e-nu's) would be cheated of their rightful numbers. SNO scrutinizes a particular reaction in the sun: the decay of boron-8 into beryllium-8 plus a positron and an e-nu. SNO's gigantic apparatus consists of 1000 tons of heavy water (worth $300 million Canadian) held in an acrylic vessel surrounded by a galaxy of phototubes, the whole residing 2 km beneath the Earth's surface in an Ontario mine, the better to filter out distracting background interactions. In 2001 SNO reported first results based on reactions in which a solar neutrino enters the detector and either (1) glances off an electron in one of the water molecules (this so-called elastic scattering (ES) is only poorly sensitive to muon and tau neutrinos) or (2) combines with the deuteron to create an electron and two protons, a reaction referred to as a "charged current" (CC) interaction since it is propagated by the charged W boson. The SNO data, when supplemented with ES data from the Super Kamiokande experiment in Japan, provided preliminary evidence a year before for the neutrino-oscillation solution for the solar neutrino problem.

Now the definitive result has been tendered by SNO scientists at the April 2002 APS meeting in Albuquerque. The new findings update last year's CC and ES data and introduce, for the first time, evidence deriving from a reaction in which the incoming neutrino retains its identity but the deuteron (D) is sundered into a proton and neutron; this is why SNO went to such trouble and expense of using D_2O-for the weakly bound neutron inside each D. This interaction, called a neutral-current (NC) reaction because the operative nuclear voltage spreads in the form of a neutral Z boson, is fully egalitarian when it comes to neutrino scattering; unlike the 2001 ES data, the NC reaction allows e-nu's, mu-nu's, and tau-nu's to scatter on an equal footing.

The upshot: all the nu's from the sun are directly accounted for. The missing nu-e flux shows up as an observable mu-nu and tau-nu flux. This conclusion is established with a statistical surety of 5.3 standard deviations, compared to the less robust 3.3 of a year before. (Ahmad *et al.*, *Phys. Rev. Lett.* **89**, 011301, 2002.)

COLD ANTI-HYDROGEN ATOMS have been made and detected, for the first time, by two groups at CERN. The ATHENA collaboration makes the anti-H atoms when a swarm of antiprotons is loosed upon a cloud of positrons held within the same trap. Anti-H atoms announce their presence when they drift out of the trap region and annihilate with ordinary atoms in a sort of double suicide. The antiproton perishes when it meets a regular proton, resulting in the creation of a few pi mesons detected in silicon microstrips, a process which points to the annihilation vertex with a precision of 4 mm. Meanwhile the positron partner from each anti-H meets its separate fate when it collides with the nearest electron, producing a telltale pair of 511-keV gamma rays which show up in adjoining CsI crystals. (Amoretti *et al.*, *Nature*, posted online, 18 Sept 2002.)

Meanwhile, the ATRAP collaboration has also detected antihydrogen atoms, but in a more direct way, through a process called field ionization, which works as follows. Having formed in the center of the enclosure, neutral anti-atoms are free to drift in any direction. Some of them annihilate but others move into an "ionization well," a region where strong electric fields tear the H-bar apart and the antiprotons are trapped in place, leaving the positron to move off and annihilate elsewhere. By counting the number of antiprotons one knows how many anti-atoms had arrived at the well. Every event represents an anti-atom. Moreover, one can now make a statistical study of the electric field needed to ionize the positron and deduce from this, in a rudimentary way, some information about the internal energy states of the H-bar. Thus the internal properties of an anti-atom have been studied for the first time. The observed range in principal quantum number n (n=1 corresponding to the ground state, or lowest level) goes from 43 up to 55. (G. Gabrielse *et al.*, *Phys. Rev. Lett.* **89**, 233401, 2002.)

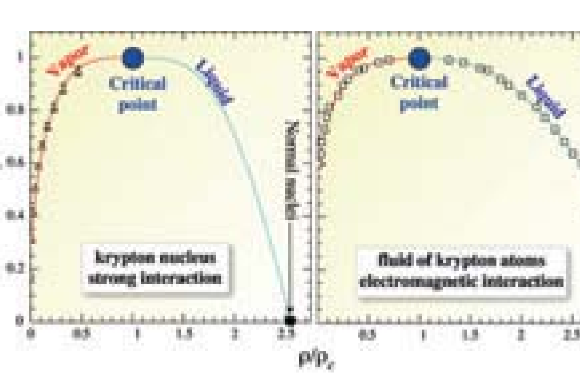
The ultimate goal of these experiments will be to trap neutral cold anti-hydrogen atoms and to study their spectra with the same precision (parts per 10^{14} for an analysis of the transition from the n=2 to the n=1 state) as for plain hydrogen. One could then tell whether the laws of physics apply the same or differently to atoms and anti-atoms.

CP-VIOLATION IN B MESON DECAYS. New reports on this important subject (important since it bears on the fundamental difference between matter and antimatter) were provided this past year by scientists from the Belle experiment at the KEK lab in Japan and the BaBar experiment at SLAC in the US. The standard model, trying to explain the forces of nature through the exchange of particles, consists of the electroweak framework (force exchanged by photons and by Z and W bosons) plus the quantum chromodynamic (QCD) framework for quarks (force exchanged by gluons). The model has been highly successful in accounting for the behavior of electrons in atoms (in the case of some transition frequencies, theory and experiment agree at the parts-per-trillion level or better) and does a good job of predicting other phenomena as well, such as CP violation. The new CP violation tests were reported at the International Conference on High Energy Physics in Amsterdam in the summer of 2002. Both Belle and BaBar observed subtleties in the decays of B mesons and measured a parameter called sine two beta. The value measured for both groups, with much better precision than ever before, is approaching the value predicted by the standard model, thus erasing past discrepancies. (See, for example Aubert *et al.* Phys. Rev. Lett. 89, 201802, 2002 and Abe *et al.*, *Phys. Rev. Lett.* **89**, 071801, 2002.)

THE g-2 EXPERIMENT at Brookhaven seeks to observe a departure of the muon's magnetic moment (related to the muon's spin by the g parameter) from 2, the value it would have in the absence of interactions between the muon and virtual particles in the universal vacuum, including possible exotica outside the standard model such as the supersymmetric entities. Although the prospective SUSY particles are rare and unstable their virtual existence in the vacuum would modify observable quantities such as the muon magnetic moment. Thus a measurement of the magnetic moment, made by watching muons decay even as they wobble about in a strong magnetic field, would give indirect evidence for the extra particles. Moderate evidence in this direction was previously reported by the g-2 team. The new results, reported also in Amsterdam, follow suit but with twice the precision of the last report. (Bennett *et al.*, *Phys. Rev. Lett.* **89**, 101804, 2002.)

A PYROELECTRIC ACCELERATOR. A pyroelectric crystal has a permanent electric dipole moment, masked by adsorbed ions on the crystal's faces until there is a change in temperature, which creates strong electric fields at those surfaces. Now, James Brownridge of SUNY Binghamton and Stephen Shafroth of the University of North Carolina, Chapel Hill, have used those electric fields to create stable, self-focused electron beams with energies as high as 170 keV. The beams were apparent in a dilute gas atmosphere, and emanated from the so-called -z face of crystalline $LiNbO_3$ after heating the +z face. The energy conversion was not especially efficient—watts of heating energy produced only microwatts of output electron beam energy—but that might not be important. Brownridge says that such a focused electron beam could be used in a portable, economical x-ray fluorescence device for the elemental analysis of complex materials like tree leaves, rocks, air filters, or blood samples. (J. D. Brownridge, S. M. Shafroth, *Appl. Phys. Lett.* **79**, 3364, 2001.)

A LIQUID-GAS PHASE TRANSITION FOR NUCLEI. In school, most physicists learned the liquid-drop model of the nucleus. In recent years, several groups have addressed the next question: Is there also an equilibrium nuclear "vapor" such that changing a parameter akin to pressure or temperature can send the nucleus back and forth between the two states of matter? Now, two groups have analyzed data from the Indiana Silicon Sphere (ISiS) experiment at Brookhaven National Laboratory, in which pions and protons were slammed into gold nuclei to induce so-called nuclear multifragmentation. A group from Michigan State University found strong circumstantial evidence for a liquid-gas phase transition, while a group from Lawrence Berkeley National Laboratory was able to fully map out a liquid-vapor coexistence line, with a critical point, in the nuclear phase diagram. That a finite system like a nucleus, with only about 200 particles, not only shows a robust phase transition but also has discoverable quantities like vapor pressure, evaporation enthalpy, and surface energy is "very exciting," according to Luciano Moretto, the leader of the Berkeley group. (T. Lefort, L. Beaulieu *et al.*, *Phys. Rev. C* **64**, 064603-4, 2001; M. K. Berkenbusch *et al.*, *Phys. Rev. Lett.* **88**, 022701, 2002; J. B. Elliott *et al. Phys. Rev. Lett.* **88**, 042701, 2002.)



Phase diagrams for two analogous systems: (left) the nucleons in a krypton nucleus and (right) Krypton atoms in a gas (Courtesy LBNL).

A TABLETOP NEUTRON SOURCE is being used to calibrate a dark-matter detector. Expected to be the dominant type of matter in the universe, dark matter interacts only very weakly with normal matter. Like a neutrino detector, a dark-matter detector will succeed only if it has enough target atoms with enough mass, operates over an adequately long period, and has sufficient background suppression. In one prototype detector using both liquid and gaseous xenon, an incoming weakly interacting massive particle (WIMP) would strike a Xe nucleus and produce both scintillation light and free electrons from ionized Xe atoms, a process strikingly similar to elastic neutron-Xe interactions. Therefore, to calibrate the detector, physicists at Imperial College, London, aimed neutrons into the Xe bath using an inexpensive and compact plasma focus discharge device as a neutron source. Deuterium fusion reactions in a pinched plasma produced helium-3 nuclei plus forward-directed 2.45-MeV neutrons. The tabletop neutron source (a pulsed device that delivers about 20 million neutrons per shot) might also be handy for the detection of nitrogen-based explosives or in the transmutation of nuclear waste. (F. N. Beg *et al.*, *Appl. Phys. Lett.* **80**, 3009, 2002.)

MICROSATELLITE PLASMA PROPULSION. Thanks to new MEMS microelectromechanical systems) technology, the development of low-mass spacecraft—less than 20 kg—has gone well, with one notable exception: suitably miniaturized thrusters, the minirockets that steer the craft and make other flightpath adjustments. John Foster, a researcher at NASA's Glenn Research Center in Cleveland, Ohio, has now built a tiny propulsion system that develops thrust from a pressurized gas of xenon that is ionized by energetic electrons as it escapes through 0.18-mm apertures. Foster boiled the electrons off a filament and used a cusp in a magnetic field to focus them onto the apertures. The resulting ions were then accelerated to the 50-200 eV range to generate thrust. Only about 50 mm across, the device is extremely fuel-efficient: 88% of the fuel is successfully turned into ions. The new compact plasma accelerator could also be used for modifying surface chemistry and making thin films. (J. E. Foster, *Rev. Sci. Instrum.* **73**, 2020, 2002.)

Test firing of a compact plasma accelerator device (Courtesy NASA Glenn Research Center)

LASER-DRIVEN JETS OF CARBON AND FLUORINE have been produced at the rear of thin foil targets. Using the powerful laser at the Laboratoire pour l'Utilisation des Lasers Intenses (LULI) in Palaiseau, France, a multinational group of physicists aimed 300-fs pulses at 50-mm-thick metal foil targets coated on the rear side with a thin layer of either carbon or calcium fluoride. First, the physicists heated the target to remove contaminants. The laser then generated, at the front of the target, relativistic electrons that penetrated the foil and shot out the back side. Those freed electrons set up a strong space-charge field that ionized atoms near the foil's back surface and then accelerated those ions outward. The researchers succeeded in accelerating fluorine and carbon ions, both having several different charge states, to energies that exceeded 5 MeV per nucleon and within a distance of only about 10 mm. Furthermore, the jets were bright (10^{12} particles per burst) and well collimated, possibly making them useful for future work in particle physics or fusion. According to team member Manuel Hegelich, an outgoing beam of fluorine ions could be used to heat a 100-mm-sized secondary target to a temperature of 200-300 eV (equivalent to 100,000 K) in mere picoseconds. During that tick of time, the crystal of atoms in the target would be heated isochorically (the lattice would not have time to expand), and thus approximate the condition inside stars. Previously, several groups have similarly accelerated protons. (M. Hegelich *et al.*, *Phys. Rev. Lett.* **89**, 085002, 2002.)

THE FRAGMENTATION OF POSITRONIUM owing to collisions with helium atoms has been experimentally investigated. The lightest "atom" made of an electron and a positively charged mate is not hydrogen but positronium, a bound electron-positron pair. Ps lives for only about 140 nanoseconds before its constituents annihilate each other, but that can be long enough to do an experiment. In recent years, physicists have been able to generate Ps beams and measure total cross sections for Ps scattering from various targets. Now, a team of physicists at University College London has conducted an experiment in which Ps scatters inelastically off helium atoms and splits apart. The separated electrons and positrons continue to be highly correlated, and the measured cross section is in good agreement with a coupled-state calculation. A longitudinal-energy peak suggests that some of the resulting electrons are lost to the continuum. (S. Armitage *et al.*, *Phys. Rev. Lett.* **89**, 173402, 2002.)

OTHER PHYSICS HIGHLIGHTS

THE 2002 NOBEL PRIZE FOR PHYSICS recognizes work that led to the establishment of two new branches of astrophysics, those involving x rays and neutrinos. The award will be presented to Raymond Davis (University of Pennsylvania and Brookhaven Natl. Lab), Masatoshi Koshiba (University of Tokyo), and Riccardo Giacconi (Associated Universities Inc.). In the 1960s Davis was the first to detect neutrinos coming from the sun. The number of nu's recorded fell short of predictions made by John Bahcall (Institute for Advanced Study) and thus was born the "solar neutrino problem." Later detector experiments, such as Kamiokande, SAGE and Gallex, also failed to observe the expected number of neutrinos from the sun. The best explanation for the shortfall was that electron neutrinos made in the solar core, as products of nuclear fusion reactions, might be transforming while in flight toward Earth into other types of neutrino such as muon neutrinos, which could not be recorded in terrestrial detectors.

This hypothesis was put to the test in the Kamiokande detector, which had earlier sought to find evidence for proton decay. Koshiba and his collaborators enlarged the Kamiokande detector and finally affirmed (by observing asymmetries in cosmic-ray-engendered nu's coming through the Earth to the detector or directly into the detector from Earth's atmosphere) that nu's were indeed transforming, or "oscillating." Still more proof for the oscillation principle arrived in 2002 when the Sudbury Neutrino Observatory (SNO), capable of directly detecting all three types of neutrino, reported that all solar nu's (albeit not the same mix as was produced in the sun) were accounted for.

As for x-ray astrophysics, Giacconi was the first to employ an x-ray telescope in space (1962) and observe specific x-ray sources outside our solar system. There followed decades of new orbiting x-ray telescopes (*e.g.*, ASCA, RXTE, ROSAT, Einstein, Yokhoh, Chandra) and notable x-ray discoveries, such as the detection of an x-ray background, resolving that background mostly into point sources, and the detection of x rays from a variety of sources, such as comets, black holes, quasars, and neutron stars.

A TINY MICROPHONE DIAPHRAGM based on fly ears has been built. Ronald Miles (SUNY Binghamton) and his colleagues based their diaphragm on *Ormia ochracea*, a small parasitic fly that uses sound to track down its cricket host even in complete darkness. The fly can detect changes as small as two degrees in a sound's direction. Such directional sensitivity—

Highlights of Science Policy and Budget Developments in 2002

JANUARY: OSTP Director John Marburger predicts that war on terrorism will not divert the conduct of science in the U.S. At a January astronomical society meeting, Marburger says Bush Administration "values discovery-oriented science." DOE Secretary Spencer Abraham expresses willingness to reconsider U.S. participation in the ITER fusion project. A DOE high energy physics panel identifies proposed $5 - $7 billion linear particle accelerator as centerpiece of twenty-year road map for field.

FEBRUARY: Bush Administration sends FY 2003 request to Congress with 8% increase for federal R&D, primarily for DOD and NIH. House Science Committee minority staff comments that overall civilian R&D portfolio request is "business-as-usual." Marburger states "life sciences may still be underfunded relative to the physical sciences." Science Committee Chairman Sherwood Boehlert (R-NY) later tells Marburger that if not for defense and national security needs, "this committee collectively would be madder than hell, to put it bluntly." Incoming Director of the DOE Office of Science, Ray Orbach, has an easy Senate nomination hearing.

MARCH: Appropriators roundly criticize Administration plans to cut USGS. New NASA Administrator, Sean O'Keefe, is questioned closely at congressional hearing about ultimate size of space station. First meeting of President's Council of Advisors on Science and Technology (PCAST) is held. Friendly and low-key appropriations hearings held on FY 2003 DOE science request. Science Committee hearing sets stage for higher NSF authorization. Move to disband DOD's JASON advisory panel draws concern. Science Committee hearing on proposed cuts to ATP reveals congressional support for program.

APRIL: Administration publishes new ITAR regulations on university-based space research. Science Committee states concern about balance in federal R&D portfolio. Orbach speaks of 30-40% budget growth over next five years as appropriate for his office. Proposed underground physics laboratory at South Dakota's Homestake Mine draws attention. House appropriators express strong support for NSF funding. O'Keefe outlines his vision for NASA. Marburger describes "balance" as a misleading and dangerous term when looking at science funding. Space station configuration is subject of congressional hearing and independent advisory committee report. Proposed Administration ATP reforms characterized as controversial. Congressional move to approve use of the Yucca Mountain nuclear waste repository.

MAY: O'Keefe tells appropriators that it is his "fondest hope" that a larger space station is ultimately built. Senate appropriators speak out against Administration's proposed NSF budget. Senate hearing on Yucca Mountain plan reveals range of opinion. House and Senate authorizers recommend 1.4% to 2.8% increase in total defense R&D.

JUNE: By overwhelming recorded vote, House passes legislation to authorize eventual doubling of NSF budget. Looking ahead, White House issues memorandum guiding FY 2004 R&D priorities. Secretary of State Colin Powell highlights role of science in foreign policy. Administration report acknowledges human role in global warming. President sends homeland security legislation to Congress containing prominent S&T role. House appropriators approve almost 15% increase in FY 2003 defense S&T funding. OSTP report finds neutron scattering demand exceeds supply. Senate authorizers hold hearing on NSF, with no mention of bill mirroring House bill.

JULY: Science Committee drafts S&T components of homeland security bill. Appropriators recommend increased USGS budget, rejecting proposed Administration cuts. Senate roll call vote clears another hurdle for the Yucca Mountain repository. Advisory group offers recommendations on DOE lab security. Senate appropriators vote for 9.2% increase in defense S&T. Two hearings on climate change reveal much controversy, with one senator calling Administration approach "baloney." Senate appropriators approve big increase for NIBIB at NIH, an almost 12% increase for NSF, and 2% increase for NASA. Appropriators' recommendations for DOE physics programs range from cuts to 7.5% increase.

AUGUST: Senate appropriators reject proposed Administration cuts in ATP. Teacher quality grant funding receives 8.8 % increase in Senate bill, but specific funding for Education Department science and math teaching remains low. Bill introduced in Senate to double authorization for NSF.

SEPTEMBER: PCAST prepares draft letter to President Bush urging significant increases in federal research funding for physical sciences and some engineering fields. A DOE fusion advisory panel releases consensus strategy document identifying ITER participation as important step. A Senate committee proposes consolidation of NSF and Department of Education math and science partnership programs. A Senate nano-technology bill is introduced. House appropriators approve DOE bill with zero to 7.5% increases for various physics programs.

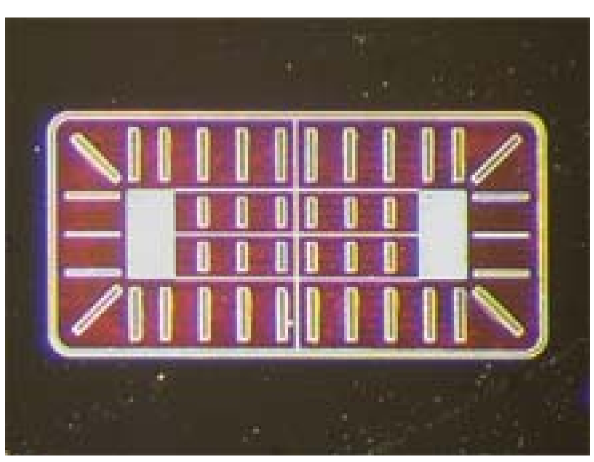
OCTOBER: PCAST meets, with no public discussion of draft letter to President Bush. Appropriators clear FY 2003 DOD bill with 16.2% increase for defense S&T programs. DOD S&T advisory board recommends that Administration allocate 3% of entire defense budget for S&T. House appropriators recommend almost 13% increase for NSF in FY 2003. House Science committee hearing on balancing homeland security with research and education. House appropriators recommend 2.7% increase for NASA, with this and Senate bill containing 11.3% to 15.9% increases for agency's S&T budget. Congress deadlocks on appropriations bills, and recesses after voting to keep spending at FY 2002 levels until January. National Academies' presidents issue statement on science and security.

NOVEMBER: Orbach appears before various DOE science advisory panels, laying out ambitious schedules and offering strong support. Congress passes bill authorizing doubling of NSF budget.

DECEMBER: President Bush signs Homeland Security Act containing S&T provisions; Lawrence Livermore National Laboratory most immediately affected. A forum in Washington addresses science and engineering workforce issues. A fusion advisory panel approves plan to put fusion-generated electricity on the grid in about 35 years. Administration seeks comments on a new climate change plan. National Science Board releases a preliminary infrastructure report. President Bush signs NSF authorization bill. Months-long FY 2003 budget stalemate continues.

Richard M. Jones
The American Institute of Physics

as good as humans'—is unexpected, since the fly's ears are just a few hundred microns apart. Mammals' ears, in contrast, are well separated from one another, so that differences in sound signals at the ears provide localization cues (see *Physics Today*, November 1999, page 24). The fly's hearing organs are a pair of mechanically coupled membranes: Sound waves incident on one membrane can deflect the other. With this coupling, the fly can obtain both the average pressure of an incoming sound and its pressure gradient, which together provide localization information. The Binghamton researchers' 2-mm^2 prototype microphone diaphragm, shown above, closely reproduced the fly ears' characteristics. This unconventional approach to localizing sound may lead to new applications, such as a compact hearing aid that responds only to sound in front of the wearer. The work was presented at a December 2001 Acoustical Society of America meeting in Ft. Lauderdale, Florida.

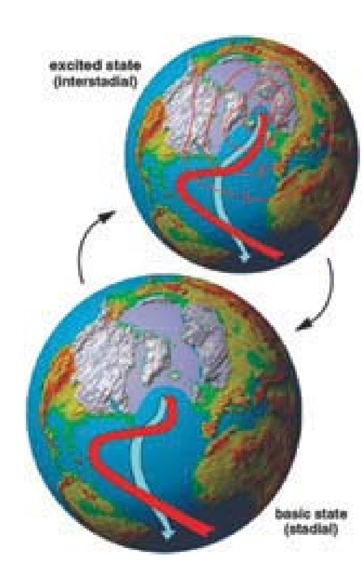


A microphone diaphragm based on fly ears (Courtesy Ronald Miles et al.)

ELEMENT 118 RETRACTION. In 1999, physicists at Lawrence Berkeley National Lab reported observing three events amid high energy collisions in which it appeared that a nucleus corresponding to element 118 had been produced; in each case the nucleus had quickly decayed into daughter nuclei. Two years later these same researchers came to believe that their analysis of the events, and therefore their claim for discovery of the element, was doubtful. (Ninov *et al.*, *Phys. Rev. Lett.* **89**, 039901(E), 2002.)

BELL LABS/LUCENT RESEARCHER DID FABRICATE DATA. The committee of independent scientists investigating charges of misconduct in the way certain Lucent experiments were performed or reported in scientific journals finally issued its report. The committee asserts that "The evidence that manipulation and misrepresentation of data occurred is compelling." They conclude that Hendrik Schon, but not the coauthors on his many articles, falsified and fabricated data. (http://www.lucent.com/news_events/pdf/researchreview.pdf)

DID ENVIRONMENTAL "NOISE" TRIGGER A CLIMATIC ROLLER COASTER DURING THE LAST ICE AGE? Under certain conditions, noise can paradoxically increase a weak signal's delectability and influence. This phenomenon, called stochastic resonance (SR), has been observed in settings as diverse as chaotic lasers and human reflex systems (see *Physics Today*, March 1996, page 39). Andrey Ganopolski and Stefan Rahmstorf of the Potsdam Institute for Climate Impact Research in Germany have shown that SR may have played a role in triggering 20 or so abrupt and dramatic warming events-called Dansgaard-Oeschger (DO) events-during the last Ice Age, which lasted from about 120,000 to 10,000 years before the present. Each DO event started with a roughly 10-year warming of about 10 degrees Celsius over the North Atlantic, and each lasted for up to a few centuries before cooling again. Curiously, the DO events typically were 1500 years apart, but sometimes skipped a beat and occurred after 3000 or 4500 years. The researchers used a global climate model with added environmental "white noise" in the form of random changes in the amount of precipitation and melted ice and snow entering the Nordic seas. Through the SR mechanism, that random influx of fresh water could amplify a weak underlying 1500-year signal of unknown (but perhaps solar) origin. The scientists found that North Atlantic ocean currents, on crossing a salinity threshold, could have flipped between two different states, one in which warm Gulf Stream waters reached only to midlatitudes and another in which warm waters penetrated much farther north. The SR-based model reproduces key features of the DO events and North Atlantic ocean circulation during the last Ice Age. If confirmed, this mechanism may help to explain why the Ice Age climate was so much less stable than that of the past 10,000 years, in which human civilization has thrived. (A. Ganopolski, S. Rahmstorf, *Phys. Rev. Lett.* **88**, 038501, 2002.)



Depiction of two glacial climate states: a stable "cold" mode (bottom) and an unstable "warm" mode (top).

A NEW KIND OF OCEAN WAVE HAS BEEN DETECTED. The Hawaii-2 Observatory, which sits on the sea floor between Hawaii and California, observes waves of many varieties. Some are acoustic waves that alternately expand and compress water as they propagate through the ocean at the speed of sound in water. Others are Rayleigh waves that are triggered by earthquakes and propagate as horizontal and vertical motions of Earth's crust, including the sea floor. Researchers have now detected a "coupled" acoustic and Rayleigh wave that swaps energy across the interface at the ocean's floor. Propagating at the sound velocity of water, the wave both induces motion of the seafloor sediments and creates regions of expansion and compression in the water. The new wave requires that the Rayleigh wavelength be shorter than the water's depth and that the shear velocity at the interface not exceed the water's sound velocity. The researchers speculate that similar modes might occur at the air-soil interface. (R. Butler, C. Lomnitz, *Geophys. Res. Lett.* **29**, 57, 2002.)

THE QUANTUM ORIGIN OF OXYGEN STORAGE IN CERIUM OXIDE has been elucidated. Many environmentally friendly technologies, such as catalytic converters and solid-oxide fuel cells, exploit an amazing property of solid CeO_2, also known as ceria. Under oxygen-poor conditions, ceria can release oxygen, transforming itself into Ce_2O_3. The Ce_2O_3, in turn, easily takes up oxygen under oxygen-rich conditions and changes back to ceria. Now, physicists from several universities in Sweden offer a detailed quantum-mechanical description of how these reactions occur. The researchers showed that the pivotal transition from CeO_2 to Ce_2O_3 results from the formation of an oxygen vacancy, in which the oxygen leaves behind two electrons that become localized on two nearby cerium ions. The charge on that pair of ions then changes from +4 to +3, and a series of reduced compounds form, ending with Ce_2O_3. The ability of solid cerium oxide to store, transport, and release oxygen is therefore an industrially important example of the quantum process of electron localization. (N. V. Skorodumova *et al.*, *Phys. Rev. Lett.* **89**, 166601, 2002.)

PHYSICS AND TECHNOLOGY FOREFRONTS

Protein Folding, HIV and Drug Design

by Michael Thorpe

Proteins are the smallest objects in biology with a specific function, and as such are building blocks—much like atoms in chemistry and quarks in high energy physics. Proteins have enough stability to maintain their 3D structure, while retaining the flexibility to perform simple tasks. Knowledge of the 3D structure of proteins is necessary to understand their biological functions, and also for applications like drug design.

Some History

It is difficult to pinpoint exactly when modern quantitative molecular biophysics started, but 50 years ago on 28 February 1953 is a natural entry point, when James Watson and Francis Crick completed their famous molecular model of the double helix structure of DNA, based on the x-ray diffraction work of Rosalind Franklin and Maurice Wilkins. In their paper in Nature, their understated remark "*It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material*," opened up the modern era in biochemistry.

The discovery of the structure of DNA is perhaps the most important scientific event of the second half of the 20th century. This structure introduced the idea of complementarity, in which knowing one strand determines what the opposite strand should be, with the base pairs A, T and G, C always occurring together. This pairing provides the basis for genetics and reproduction. This is all now taken for granted, but we should not forget that just months before the Watson and Crick paper, Linus Pauling had published a *three* helix model for DNA.

While DNA provides the genetic code, these are only the encoded instructions which must be decoded and implemented to be useful.

In the last 50 years, molecular biology has gradually become more quantitative. With the recent near-completion of the human, mouse and other genomes, the genetic code is now available as the base pairs of DNA. It is this sequence (ATGCAATCGA…), about 3 billion altogether, that contains all the information needed for life. DNA is largely inert—it is the computer code, but of much more interest is what happens when the program is run.

About 2% of the genetic material is genes, which are specific sequences of bases that encode instructions on how to string amino acids together to make the polypeptide chains that will then fold to form 3D proteins. At each site of DNA, there is a choice of one of the bases A, T, G, or C. Hence to encode for the 20 amino acids, it takes *three* adjacent sites of DNA, called a codon, which leads to 64 choices. This redundancy has bothered people, and many elegant encoding schemes were proposed. The truth turned out to be somewhat prosaic, with between 1 and 6 codons mapping onto each amino acid, in a many to one mapping.

To physicists who are inclined to think that nature always goes for elegance, the translation scheme from DNA, via RNA transcription, to amino acid sequence can be a disappointment. However, realizing that the complex systems of biology have evolved continuously through a series of very small evolutionary steps, we may regard biology being locally optimized. It is a design that works.

When the polypeptide chain folds into a 3D structure, it becomes a functioning protein. We are now seeing molecular biology being understood from the ground up — starting with the smallest molecular building blocks from the base pairs of DNA that encode for the amino acid sequences of proteins, to the 3D structure of proteins, to complexes containing proteins, DNA and RNA, and up to self-contained biological entities like viruses and cells.

Proteins

The forefront of molecular biophysics has now moved to proteins. Each one has a simple task, out of which something as complex as a mouse or you and I is constructed. Indeed, both have very similar sets of proteins, totaling around 30,000, with about 95% being the same or very similar. This has come as a considerable shock to some humans, but mice have remained quiet about it. The linear sequence of amino acids, as shown in Figure 1, folds as it comes off the ribosome, which is the molecular machine where the amino acids are assembled into a polypeptide chain in the right sequence, according to the genetic code. The DNA sequence for the first five amino acids of the protein HIV protease is CCT CAA ATC ACT CTT, which encodes for the amino acids proline, glutamine, isoleucine, threonine and leucine.

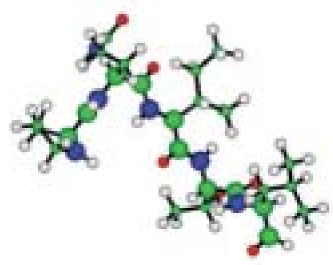


Figure 1. The first 5 amino acids of the polypeptide chain of the protein HIV protease that result from the instructions in the DNA codons given in the text. Here the green spheres are C atoms, blue are N, red are O and grey is H.

Proteins arise from exponentially unlikely sequences of amino acids as determined by evolution. The unfolded polypeptide chain is a rather uninteresting 1D random coil that has no useful function until it folds into a compact 3D protein as shown in Figure 2. How a protein folds in times that range from a microsecond to a few seconds remains the subject of much study, as the protein does not have enough time to sample all possible conformations. Thus some kind of sequential or hierarchical process must occur, where perhaps secondary structures like the alpha helices and beta sheets form first, and then they in turn come together to form a rather compact 3D structure. It is important that proteins are three-dimensional, both for functionality, and as the smallest component that defines us as three dimensional objects.

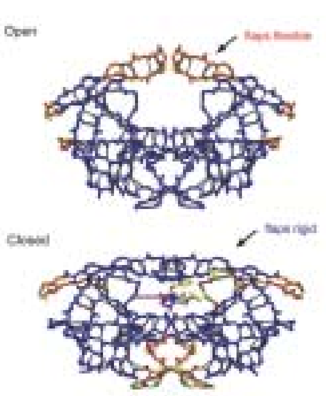


Figure 2. The protein HIV protease is a dimer that consists of 2 polypeptide chains, each containing 99 amino acids, and is an important part of the HIV virus.

Proteins are compact macromolecules that exist and function in an aqueous environment. Protein functions are very varied, such as docking against another protein, RNA or DNA, forming a channel for ions to pass through, or the proteins called proteases which can chop a polypeptide chain into segments of the right length.

Flexibility

The balance between stability and function can be studied by using *constraint theory*. The constraints associated with the unfolded polypeptide chain are the covalent bond lengths and angles, and the locking of the dihedral angle associated with rotation around the peptide bond. The additional constraints that are responsible for the 3D protein structure are hydrophobic interactions and the hydrogen bonds that act to cross-link different pieces of the polypeptide chain.

Although constraint theory only involves topology, it is necessary to know the 3D protein structure from x-ray diffraction experiments in order to assign hydrophobic and hydrogen bond constraints. In 1970, the Dutch mathematician Gerard Laman worked out a complete theory of constraints for 2D systems. This allows the rigid regions and the flexible joints between them to be identified. Some parts of the rigid regions may be over-constrained and contain redundant bonds and these are also identified.

In 1985, the mathematicians Tlong-Seng Tay and Walter Whiteley extended this work with the *Molecular Framework* conjecture, which applies to the subset of all 3D networks such as those found in macromolecules with covalent bonding, and so can be applied to proteins. It is now possible to determine the rigid regions in a 3D protein and the flexible joints between them, as shown in Figure 2. Such knowledge is important in understanding the stability and function of the protein. The lower panel in Figure 2 shows the same protein with a small ligand attached, which inhibits the function of the protein associated with the opening and closing of the two flaps at the top. These now become part of the rigid core with the ligand present. This is the basis of most drug design—shutting down the activity of one protein, while avoiding the toxicity that would result if other proteins were affected.

When proteins unfold due to environmental changes in the local pH *etc.*, or in the lab by increasing the temperature, functionality is lost. While the detailed pathways associated with this unraveling differ for different proteins, the whole process can be characterized by an overall loss of rigidity. As non-covalent bond constraints are broken, the rigid core gets slightly smaller, and then fractures into smaller rigid pieces very much like a weak first order phase transition. There is a corresponding increase in the number of independent motions associated with internal degrees of freedom that are now possible. Within the constraint approach, these motions have no restoring force associated with them, but in reality are low frequency or *floppy modes*. This viewpoint emphasizes the similarities among all proteins, and identifies the mean coordination as the reaction coordinate for protein unfolding and folding. The mean coordination is the average number of constraints per atom taken over the whole protein.

Drug Design

Rigid region decompositions, shown in Figure 2, are a useful aid in understanding protein function, and also in applications such as the search for drug candidates in the pharmaceutical industry. Drugs are small molecules with typically between 10 and 100 atoms, which attach themselves to a protein and inhibit its function. A good attachment requires a good steric fit as well as favorable van der Waals contacts. The computer screening of large databases of molecules to search for drug candidates is becoming more sophisticated using software such as *SLIDE*. Of course this is only the first step in the drug discovery process. The lower panel in Figure 2 shows how an inhibitor attaches itself to the protein HIV protease. The flaps at the top can no longer open and close, rendering the protein dysfunctional, which in this case is of course very beneficial, and has given the best success so far in the worldwide fight against AIDS.

Michael Thorpe is currently University Distinguished Professor of Physics at Michigan State University. From the middle of the year he will be Professor of Physics, Chemistry and Biochemistry at Arizona State University. He is a Fellow of the APS.

AWARDS *from page 1*

under age 30, for his or her outstanding scientific contribution to the knowledge of physics." To be eligible, a candidate must turn 30 no earlier than April 1, 2003.

Another prize open to all fields is the **Julius Edgar Lilienfeld Prize**, which carries a stipend of $10,000 and which "shall be awarded for outstanding contributions to physics by a single individual who also has exceptional skills in lecturing to diverse audiences." Last year a special canvassing committee solicited nominations for the Lilienfeld Prize with considerable success, but additional nominations are being sought this year as well to keep the pool strong and up-to-date.

The descriptively named **Prize to a Faculty Member for Research in an Undergraduate Institution** needs little further explanation. It is given for research in any field of physics performed at a non-PhD granting institution, and typically rewards a program of research that involves not only the faculty member but undergraduates as well. Both the faculty member and his or her institution receive stipends of $5000.

The **LeRoy Apker Award** was established in 1978 and is given for outstanding research by an undergraduate. Typically two awards are given each year in parallel competitions, one for research done at a PhD-granting institution, and one for research at a college or university that does not grant the PhD degree in physics. From the pool of nominees, six finalists are chosen, three in each category. The finalists each receive $2000 and their institutions $1000. The two recipients each receive $5000, and their respective institutions also are awarded $5000 to be used to support undergraduate research.

Other APS awards open to research in any field of physics include the **Edward A. Bouchet Award** which is given to recognize "a distinguished minority physicist who has made significant contributions to physics research" and is sponsored by a grant from the Research Corporation; and the **Maria Goeppert-Mayer Award**, which is given "to recognize and enhance outstanding achievement by a woman physicist in the early years of her career" and is supported by the GE Fund. Both these awards include a program in which the recipient travels to a number of institutions to present lectures on research and also to serve as a role model for the students who may be considering physics as a career.

Information on all these prizes and awards, including eligibility requirements, deadlines, and nomination procedures, may be found on the web site at **www.aps.org/praw.**

LETTERS

Bohr Misunderstood Heisenberg's Motivation

As an APS member I always read with interest the information contained in *APS NEWS*. The August/September issue came to my attention only now after my return from extended trips. Having worked under Werner Heisenberg from 1950 to 1970, and having been told by him, in 1969, at my request, about his visit to Bohr in 1941, I read with particular interest the article by Frederick Seitz "Letters Reveal New Insights Into the Bohr-Heisenberg Meeting".

This article shows a good understanding of Heisenberg's personality and of the situation in which he found himself in Nazi Germany. However, Seitz misses the main motivation of Heisenberg's visit to Copenhagen in 1941. Heisenberg had been drafted by Army Ordnance, at the beginning of the war in 1939, to work on the feasibility of an atomic bomb. By 1941 he had come to the conclusion that the production of such weapons would be possible in the long run but technically so difficult, by isotope separation as well as by the production of what is now called plutonium, that it would take many years, at least in Germany under war conditions, to make just one bomb.

Atomic weapons might decide the war only if the war dragged on long enough. Couldn't the small international community of nuclear scientists, in the meantime, come to an agreement not to build such bombs? What would Bohr, the father figure of that community, think about this idea? C.F. von Weizsaecker suggested that Heisenberg ask Bohr. A conference on astrophysics was arranged at the German Cultural Institute set up in Copenhagen for propaganda purposes by the Cultural Division of the German Foreign Ministry, of which Weizsaecker's father was the top civil servant. Bohr boycotted that Institute but for Heisenberg, lecturing at its conference together with several well-known German astrophysicists, it was the only possibility to get permission for a visit to occupied Denmark, and to see Bohr.

Heisenberg paid several visits to Bohr and to Bohr's institute on that occasion. At one of them, Heisenberg began to tell Bohr about the technical feasibility of nuclear bombs, in very involved language so that Bohr would understand but not any potential Gestapo eavesdropper. But Bohr did not want to listen when this subject came up. He was upset and excited. He misunderstood Heisenberg's indirect hints as meaning that Heisenberg was trying to build the bomb whereas Heisenberg had only meant to say that he understood the problem after two years of studying, and that the construction, very difficult and at present not feasible anyway, could still be avoided. Moreover, Bohr resented Heisenberg's suggestion that Bohr give up his boycott of the German Cultural Institute although, as Bohr's unsent letters now show, Bohr realized that Heisenberg was motivated by his concern for Bohr's future safety and well-being. In September of 1941 it looked as if Germany might win the war.

In any case, Bohr's anger cannot have been very deep. Two days after his ill-fated discussion with Bohr on the bomb, Heisenberg paid another visit to Bohr at Bohr's home. On that occasion they avoided politics, they discussed physics, Heisenberg played the piano, and Bohr read a story to him. As Heisenberg wrote to his wife while still in Copenhagen, it was a harmonious meeting just as in the old days. Heisenberg posted this letter after his return to Germany to avoid censorship. It was found only recently by the Heisenberg family among private papers and is partly published by H. Rechenberg in the forthcoming proceedings of the Heisenberg Centennial of the Saxonian Academy of Sciences.

Regarding the remark by Fermi's student quoted by Seitz at the end of his article: It seems that Heisenberg never looked as if he had ever done "anything important." He was said to look like a farm boy at the time he discovered the uncertainty principle. When I first met Heisenberg in 1949 I thought that he looked like a successful, good-natured, reasonably athletic, down-to-earth owner of a medium-sized business, not at all like a deep thinker oblivious of his surroundings. His high spirits revealed themselves in discussions only.

Klaus Gottstein
Munich, Germany

Create a Physics Piggy Bank

John Marburger deserves great praise for his Back Page article, "Tell the truth about particle physics. "(APS News, December 2002). It is the most articulate and coherent presentation of the justification for Big Physics—in fact, for physics projects on any scale—that I have read, as well as being a realistic description of the funding environment in which big science projects must live (or die). I believe that we are fortunate indeed to have someone of his capabilities in a key policy position.

The only observation that I would add to his discussion is that big science projects have no necessary schedule for their initiation, except perhaps in times of great crisis. This suggests to me that there are other options for funding such projects besides the traditional massive commitment by Congress, an approach that suffers from the political instabilities that Marburger notes.

One alternative might be for Congress to enact, and NSF to manage, small set-asides for each discipline each year that could accumulate untouched until a fund reaches the size needed to carry out a big project on which, *e.g.*, the particle physics community could agree. While such a fund could be vulnerable to increasing political pressures within a given discipline as the fund grew, it would be largely isolated from external factors.

I imagine that there are many more practical ways in which individual big science projects could escape the fate of the SSC, but I suspect that any successful general strategy will hinge on the fact that doing worthwhile science, big or small, is essentially a timeless endeavor.

William F. Hall
Thousand Oaks, California

Elephant's Area Important

I enjoyed reading about the 2002 Ig Nobel Prizes in the December *APS News*. I was, however, a little surprised to see among the listed winning topics "Estimation of the Total Surface Area In Indian Elephants." It might sound like a frivolous, pedantic topic, but knowing the surface area of an animal is not quite as trivial as one might suppose. The total surface area determines an animal's rate of heat loss and their basal metabolic rate (BMR). In veterinary medicine, drug dosage (*i.e., # of mgs*) is based on estimates of total surface area, not on kilograms of body mass, because it is the BMR which determines how fast the drug will be metabolized. This is still partially true in human medicine and dates back to the early 20th century, when a husband and wife physiology team (du Bois and du Bois) actually pasted pieces of paper on to human subjects in order to determine their total surface area and to develop a semi-empirical formula that would estimate it using body length, which is easily measured.

Michael D. Delano
Brooklyn, New York

Economic Assistance Key for Students of Color

The article by Ken Krane (*APS News*, Back Page, November, 2002) is an enlightening and welcome report on attempts by a task force to identify success factors that attract students to enroll in physics curricula. I find the report to be consistent with the increasing effort to populate the human resources physical sciences pool, not only to provide professionals in physics but also to augment the capability of professionals where the knowledge of physics continues to play such an indispensable role in recent developments of other fields. In fact, the value of these developments prompts me to wonder if in due course "physics" will go the way of "natural philosophy" as known in earlier times. While this thought might bear consideration in the design of future curricula, it should not detract from the course reported by Krane.

The article alludes to the difficulty of attracting women and minority students into the physics curricula. Among the factors that the task force is cited to have singled out as one measure of a "thriving undergraduate physics program," is the presence of a "significant representation of women and minorities." The article also indicates the task force will focus on this topic in a meeting held this month.

Whatever may be the outcome of said meeting, I wish to cite my experience related thereto, particularly since I was asked recently to offer my view on the reason "students of color" have less preference for pursuing studies in physics as compared to other sciences. One of my immediate suggestions was that the practical value of other sciences is ever more evident in use of household goods, *e.g.*, use of disinfectants (chemistry and medicine), cultivating plants, especially use of herbs (biology), etc. In this case, familiarity breeds attraction. I also recalled an earlier posed personal view that the unfavorable socioeconomic conditions experienced by students of color detract from pursuit those careers that require relatively long term study when choosing to remain a contributing family breadwinner is of higher priority.

The desired response to the above cited first view seems clear. In this connection, perhaps an important opportunity was missed in not communicating effectively the role of physics in the evolution of our space program. Rightly so, the role of engineering in this national effort was properly communicated with due recognition that an entire federal agency was dedicated to it. As for the socioeconomic factor, it also seems clear that where the proper economic assistance is available for a particular course of study, students of color will gravitate toward it. The best evidence offered for this view is the support that the National Institutes of Health (NIH) has devoted to attracting students of color since 1974—nearly 30 years of sustained interest—when the first effort began. My visits to colleges and universities to encourage students to pursue careers in the physical sciences illustrates that the principal competition for drawing students of color into these areas comes from the NIH-supported biomedical programs that offer students viable and long term support for their education. A survey of the results achieved by these commendable NIH programs should bear out this point.

The one program in the physical sciences that has shown unquestionable success in my view is the one initiated by Bell Labs and co-designed by the Society's Committee of Minorities, of which I am one of five founders. I would be remiss if I did not acknowledge the indispensable role that Bell Labs employee, Joseph Burton (then APS Treasurer and since deceased) played in facilitating this interaction. The Bell Labs program was designed to take undergraduate physics students of color and provide them the long term support through the doctorate degree. Thus, I offer that the obstacle to attracting students of color into physics is basically one of economics. In addition, any efforts by the Society to make better known the value of physics to parents, guardians and younger students under their charge, would lend strong collateral incentive for attracting students to the physical sciences.

J. V. Martinez
Bethesda, MD

Book Gives Perspective on Science and Religion

There are fundamental scientific questions that intrigue prominent scientists that ought not be characterized as pseudoscience and thus be prevented from being discussed in science classes. Lawrence M. Krauss [*APS News*, August/September 2002] dismisses such questions when he disparages intelligent design and casts it together with young earth creationism, UFO sightings, etc.

I should like to recommend the book "Cosmos, Bios, Theos: Scientists Reflect on Science, God, and the Origins of the Universe, Life, and Homo sapiens," edited by H. Margenau and R. A. Varghese. This anthology presents the perspective on the relationship between the scientific enterprise and the religious view of reality. Contributors include over twenty Nobel Prize winners and distinguished scientists from different disciplines.

Moorad Alexanian
Wilmington, North Carolina

THE BACK PAGE

Speeding up the Long Slow Path to Change

by Meg Urry

It's 2002 and there are still physics departments with no women faculty, and many more with no minorities. The trends are generally in the right direction, but change is painfully slow, in marked contrast to progress in the equally demanding disciplines of biology, chemistry, engineering, mathematics, and medicine. So why has physics proved so resistant to change?

When I (gently) ask my colleagues around the country why they hire mostly or only men, they say there simply are no women available to hire. But the top 10 physics departments graduated 138 women with PhDs in physics in the five-year period 1988-1992 (10.7% of total PhDs). Twenty to thirty of the top physicists produced each year are women. In 2000, 13% of physics PhDs went to women. Women are indeed available.

Recruitment is often targeted, however, perhaps more so in the more elite universities. They want the best, and they don't expect them to float up through the applications process. Thus, hiring women requires (a) valuing their talents, and (b) thinking of them when a job (or talk or prize) is at hand. This does not appear to happen automatically. So where are we falling down? My physics colleagues are good people. They do not discriminate, they would not deny opportunity to women because they are women. So where is the problem? Let me try to answer this question with three stories.

1. The powerful act powerless—the system worked for them, and they expect it to work for everyone. At the March 2002 APS meeting in Indianapolis, the chair of a large physics department at a major Midwestern university pointed out what he sees as the problem. "At the beginning of my introductory physics class," he explains, "I ask which students are planning to major in physics, and the women do not raise their hands!" His department is responsible for graduating many physics majors and PhDs, yet he is convinced that women simply don't like physics and there is nothing he can do to change their minds. He and his colleagues feel powerless to affect gender imbalance. Another physicist nods his head in agreement, convinced that women are simply more interested in other fields, like biology and chemistry.

But the young students in the physics chair's class are new to the discipline. Perhaps they have never had a physics class before, or perhaps their high school class did not catch their imagination. Is it necessary that they know they love physics before they've studied it? Is early certainty of one's vocation a sign of one's talent for it? Should physicists come only from the ranks of those who enjoy what may have been a boring, rote-like class with little connection to modern physics research? Shouldn't physics professors take as their responsibility the mission of showing students how very interesting and rewarding physics can be?

But most professors teach physics the way they were taught. This is where the problem starts to become clear. The students in class today are not junior versions of their professors. Their paths in life have been different, their interests may be different, their approaches to science may be different. Yet we still define the best students as being those who are just like us. This solipsistic approach stems from the relative homogeneity of our physics faculty, and it reinforces that homogeneity. Yet diversity historically has led to intellectual breakthroughs; the greatest new ideas are born in the roiling waters at the confluence of different rivers of thought. A narrow set of views and styles in physics will benefit no one—not women and minorities, and most importantly, not the science.

(2) *"You're not a member of my club."* A young woman physicist, an assistant professor at a small but excellent four-year college— energetic, smart, talented, attractive, and with a friendly personality—goes to the 2002 APS March meeting in Indianapolis to give a talk. She wanders through the convention center and separately encounters three women physicists. They all smile and offer to help her, as she is obviously just arriving. But they don't have the program and the registration desk has closed for the night. She walks over to a group of young men about her age, who are sitting and talking nearby. She stands politely waiting for them to acknowledge her. But apparently what they are discussing is so earthshaking that they fail to notice her presence. Finally, she butts in and asks if anyone has the program for the next day. "Certainly not," answers the first man, annoyed at the interruption. "Why would I carry that around? It's heavy." The second chimes in and lets her know how stupid her question is and how her presence is interrupting their important discussion. She turns away, uncomfortable and upset, and the next day is still fretting about this episode.

This story demonstrates that some young male physicists can be boors, perhaps, but more that it is all too easy for women physicists to feel ill at ease and out of place. There are few role models for most of us. There are few women faculty and few fellow female students. Women physicists have no clear path in front of them, no clear connection between where they are (pursuing physics) and where they want to be: advancing in the profession.

Meg Urry

It is no wonder that women physicists tend to have greater self-doubt than men. In a study at MIT, graduate students in male-dominated science and technology fields were asked to rate their own abilities, and their professors were asked to rate them as well. The actual distributions of ability for men and women did not differ, according to the professors, but the self-evaluations did. On average, the women rated themselves below average and the men rated themselves above average.

In physics departments around the country, women are feeling ill at ease, out of place, not at home. Often it's as simple as statements about what makes a good scientist, or what some famous scientist was like. Think of our heroes: read Feynman's autobiography and tell me what you thought. Maybe you liked him, maybe you hated him, maybe you envied him —but probably you didn't feel as uncomfortable as his women readers did. Several wives go unmentioned or at least undescribed, and women in general appeared to play a remarkably small role in his life—except for the ones he was trying to date.

> *"We are almost all prejudiced in the sense that we have absorbed the gender and race stereotypes that prevail in our society."*

3) *Sociology holds some of the answers, if physicists would only listen*. Studies have shown that referees judge gender of author, not quality of work. In 1983, Paludi and Bauer published a revealing study about the influence of gender on perception of excellence. Three-hundred-sixty referees, half men and half women, were each sent a mathematics paper to rate, with the author's name given variously as John T. McKay, Joan T. McKay, or J. T. McKay. The reviewers found that the man's paper was considerably better than the woman's. The neutral, initials-only designation was also rated rather lower than the man's paper, apparently because many referees believed the initials to represent a woman. Both men and women found the paper written by the woman to be markedly less good than the man's paper. So it isn't just men undervaluing women's work, it is all of us.

Gender-based bias can also be found in the literary/artistic world. The Modern Language Association referees abstracts submitted for its annual meeting before accepting them. In 1974, the MLA began "blind" refereeing, in which the referees were no longer told the authors' identities. Prior to this, women had given very few papers at MLA meetings. Within a few years of the change, women were giving papers in roughly the same percentage as in the submitted abstracts. A similar shift to blind auditions for the world's great orchestras has greatly increased the number of female musicians accepted.

A few years ago *Nature* published several articles about gender bias in applications for research support from the Swedish Medical Research Council. Two researchers obtained the applications and the grades and comments. They found that women had to have published much more, and had to have been rated much more highly, in order to have an equivalent chance at the fellowship. In quantitative terms, a woman had to be more than twice as good as a man to rank equally on the final list.

These results agree well with longitudinal studies of women and men PhD scientists, closely matched in ability and field, which found strong evidence of lesser advancement for even very talented women. Even taking into account variables like family status and productivity, the overwhelming predictor of success was gender. Women were paid less, were less likely to be hired into faculty positions, took longer to get tenure, and fewer got tenure than the men.

Your female colleagues are subjects of sociological experiments every day, when they are interrupted and their speech occupies a smaller fraction of the discussion, when their idea is dismissed or overlooked but lauded if a man suggests it a few minutes later, when students are skeptical of their expertise but unhesitatingly assume male professors are fully competent. The popular image of success, of competence, of science, is male. We are almost all prejudiced in the sense that we have absorbed the gender and race stereotypes that prevail in our society. The best any of us can do is to recognize it and correct for it, long enough to change the face of science, and thus to render obsolete the present stereotypes.

So what is the strategy for moving forward? Clearly, we need to raise awareness about the extra barriers for women. These sociological barriers affect many other arenas besides physics, but physics is still lower in the percentage of women and slower/harder to change. My own speculation is that physics is more hierarchical, more elitist, than other professions, and thus women's feelings of inadequacy are exaggerated. The effect on women is therefore harsher in physics. It's an hypothesis that bears testing, if we can find an objective way to assess elitism.

Meanwhile, there are a few common sense recommendations. First, let us not assume others are like us. Interest in physics comes at different stages and manifests in different ways. Female talent is out there—let's look for it and nurture it. If girls and women come forward less readily, let's not interpret that as disinterest or reluctance or lack of skill. Second, we must compensate for the lack of role models, offer better support, and teach parents, teachers, guidance counselors to encourage interest from girl proto-scientists. Third, women who have persisted past the barriers may well feel isolated, invisible, and marginalized. No women or men should imagine the playing field ever really levels out. We hope it will someday, but there is no evidence that it has done so yet.

I believe there is good reason for optimism. The percentage of physics PhDs going to women is increasing, albeit slowly. Some senior male colleagues are taking this challenge as their own, and have helped effect change. The number of women hired as junior faculty may be even be roughly the same percentage of assistant professors as of postdocs. Finally, the dearth of women in physics is receiving serious, concentrated attention, as in the national Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development report *(See www.nsf.gov/od/cawmset/start.htm)* and the International Conference on Women in Physics *(See www.if.ufrgs.br/~barbosa/conference.html)*. But we cannot wait complacently for physics to enter the modern era in gender equality. It is too difficult a problem and only persistent pressure will make the big beast move.

Meg Urry is a professor of physics at Yale University. This article was adapted from a longer article that appeared in the fall 2002 issue of The Gazette, *the newsletter of the APS Committee on the Status of Women in Physics.*

APS News welcomes and encourages letters and submissions from its members responding to these and other issues. Responses may be sent to: letters@aps.org.