Members in the Media

"These are baby problems,"
***Peter Limon**, Fermilab, describing the initial problems most accelerators, including CERN, experience early in their operating lives,* The New York Times, *August 4, 2009.*

"As a physicist, my big complaint was that people don't consider the odds and worry about things that are terribly unlikely…I never worried about things that were unlikely, and it came back to bite me."
***Robert Park**, University of Maryland, describing when he was nearly killed by a falling tree,* The Philadelphia Inquirer, *August 10, 2009.*

"I don't see it in quite those apocalyptic terms…Everyone there was unhappy about the earlier accident, but I didn't get the feeling that there was panic or that they were resigned to anything but a delay."
***Steven Weinberg**, University of Texas, Austin, talking about the mood at CERN,* The New York Times, *August 8, 2009.*

[T]he LHC is an example of an enormously complicated machine that is pushing the edge of accelerator technology, and it is not surprising that it has had some unanticipated problems,"
***Neal Lane**, Rice University,* The Associated Press, *August 7, 2009.*

"What the U.S. and China do over the next decade will determine the fate of the world."
***Steven Chu**, Department of Energy,* Time, *August 13, 2009.*

"These neutrinos are a type of matter that essentially form a shadow universe…They share space with us, but they have very little interaction with us. So you have neutrinos going through your body all the time–neutrinos from the sun, neutrinos from the cosmic rays coming down from space, neutrinos left over from the birth of the universe–but they go right through you."
***Marvin Marshak**, University of Minnesota,* The Washington Post, *August 17, 2009.*

"A big part of the worldwide neutrino program is to gather evidence that neutrinos in fact had a role in making the universe asymmetric,"
***Boris Kayser**, Fermilab,* The Washington Post, *August 17, 2009.*

"[Jennifer Mass] is one of an emerging, growing group of scientists who have a foot planted in both worlds,"
***Sol Gruner**, Cornell, describing Mass's discovery of a lost N.C. Wyeth painting using X-rays,* The Philadelphia Inquirer, *August 20, 2009.*

"If somebody sneezed on that kilogram standard, all the weights in the world would be instantly wrong,"
***Richard Steiner,** NIST,* National Public Radio, *August 20, 2009.*

"If Advanced LIGO doesn't see gravitational waves I think people will be very surprised…It is likely such a situation would require revision of General Relativity."
***Vuk Mandic,** University of Minnesota,* MSNBC.com, *August 19, 2009.*

"We have respected people on both sides of the medical profession speaking very loudly and now with greater and greater vitriol as to whether that theory is legitimate… We've got to have somebody like the National Academy of Sciences look at all of the studies that are put forth as validating that theory–and see whether they're valid."
***Thomas Bohan**, MTC Forensics, calling for a definitive verdict on the cause of shaken baby syndrome,* National Public Radio, *Aug 24, 2009.*

"[H]ere's a case where you shine a laser on something and it actually cools down, and not just a handful of atoms, but a macroscopic object,"
***Trey Porto,** NIST, describing a new technique developed by a German research team,* National Geographic, *September 8, 2009.*

"We rent one early-bearing tree and one late-bearing tree…It's a nice feeling knowing that's my apple tree."
***Richard Raymond**, University of Michigan, on renting apple trees from an orchard,* Detroit Free Press, *September 10, 2009.*

"There are a number of demonstrably false claims which have been put forth such as there is no evidence, one can't get here from there, governments can't keep secrets, if aliens were visiting they would want to talk to me or land on the White House lawn,"
***Stanton Friedman**, describing his research into flying saucers,* The Denver Post, *August 9, 2009.*

This Month in Physics History

October 22, 2004: Discovery of Graphene

Scientists often find ingenious ways to attain their research objectives, even if that objective is a truly two-dimensional material that many physicists felt could not be grown. In 2003, one ingenious physicist took a block of graphite, some Scotch tape and a lot of patience and persistence and produced a magnificent new wonder material that is a million times thinner than paper, stronger than diamond, more conductive than copper. It is called graphene, and it took the physics community by storm when the first paper appeared the following year.

The man who first discovered graphene, along with his colleague, Kostya Novoselov, is Andre Geim. Geim studied at the Moscow Physical-technical University and earned his PhD from the Institute of Solid State Physics in Chernogolovka, Russia. He spent two years at the Institute for Microelectronics Technology before taking a fellowship at Nottingham University in England. In 1994, he joined the faculty at the University of Nijmegen in the Netherlands, moving back to England's University of Manchester in 2001 to become director of the Centre for Mesoscience and Nanotechnology.

Scanning electron micrograph of a strongly crumpled graphene sheet on a silicon wafer (Foundation of Fundamental Research on Matter, the Netherlands).

Geim has a knack for quirky yet significant research subjects. He made headlines in 1997 when he used a magnetic field to levitate a frog, garnering him an Ig Nobel Prize in 2000. He once co-authored a paper with his favorite hamster, "Detection of earth rotation with a diamagnetically levitating gyroscope," insisting that "H. A. M. S. ter Tisha" contributed to the levitation experiment "most directly." (According to Wikipedia the hamster later applied for a PhD at the University of Nijmegen.) And in 2007 his laboratory developed a microfabricated adhesive mimicking a gecko lizard's sticky footpads.

Geim has said that his predominant research strategy is to use whatever research facilities are available to him and try to do something new with the equipment at hand. He calls this his "Lego doctrine": "You have all these different pieces and you have to build something based strictly on the pieces you've got." In the case of graphene, his lab was well-equipped for the study of small samples.

Carbon nanotubes were–and are–a major area of materials research, and Geim thought it might be possible to do something similar to carbon nanotubes, only in an unfolded configuration. He had the idea to polish down a graphite block to just 10 or 100 layers thick and then study the material's properties. One of his students was assigned the task, and produced a speck of graphite roughly 1000 layers thick–a little short of the mark.

That is when Geim had the idea to use Scotch tape to peel away the top layer. Flakes of graphite come off onto the tape, and the process can be repeated several times to achieve progressively thinner flakes attached to the tape. He then dissolved the tape in solution, leaving him with ultra-thin flakes of graphite: just 10 layers thick. Within weeks, his team had begun fabricating rudimentary transistors with the material. Subsequent refinements of the technique finally yielded the first graphene sheets. "We fooled nature by first making a three-dimensional material, which is graphite, and then pulling an individual layer out of it," said Geim.

In October 2004, Geim published a paper announcing the achievement of graphene sheets in *Science* magazine, entitled "Electric field effect in atomically thin carbon films." It is now one of the most highly cited papers in materials physics, and by 2005, researchers had succeeded in isolating graphene sheets. Graphene is a mere one atom thick– perhaps the thinnest material in the universe–and forms a high-quality crystal lattice, with no vacancies or dislocations in the structure. This structure gives it intriguing properties, and yielded surprising new physics.

From a fundamental standpoint, graphene's most exciting capability is the fact that its conducting electrons arrange themselves into quasi-particles that behave more like neutrinos or electrons moving close to the speed of light, mimicking relativistic laws of physics. In most materials, charge carriers behave in a more classical fashion. Geim has compared the effect to the Large Hadron Collider, "but on your desktop." This makes it possible to test certain ideas in particle physics and astrophysics conceptually on a smaller tabletop scale, rather than in a multi-million dollar collider.

The most obvious application is using graphene to replace silicon chips, since that technology is fast reaching its fundamental limits (below 10 nanometers). It is also possible to make graphene using epitaxial growth techniques–growing a single layer on top of crystals with a matching substrate–in order to create graphene wafers for electronics applications. So graphene holds promise for use in high-frequency transistors in the terahertz regime, or to build miniature printed circuit boards at the nanoscale. There are technical barriers: graphene is metallic, so scientists would need to devise a way to make the material semiconducting. They will also need to develop a technique for producing graphene sheets in large quantities if the material is to find application in large-scale industrial sectors.

For now, graphene is being explored as a filler in plastic to make composite materials, in much the same way that carbon nanotubes are used to bolster the strength of concrete materials, for example. Graphene suspensions can also be used to make optically transparent and conductive films suitable for LCD screens.

Graphene may even have the power to tame Geim's notorious five-year itch: that is how frequently he has tended to change research topics in the past. Yet he has even set aside his promising gecko tape research to focus predominantly on graphene, which he admits is by far the most scientifically significant of his results. "With graphene, each year brings a new result, a new sub-area of research that opens up and sparks a gold rush," Geim told *Science* in 2007. "I want to put many more stakes in the ground before it's covered completely, before all the interesting science is claimed and taken. Then it will be time to move on."

APS NEWS

Series II, Vol. 18, No. 9
October 2009

Coden: ANWSEN ISSN: 1058-8132

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

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

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