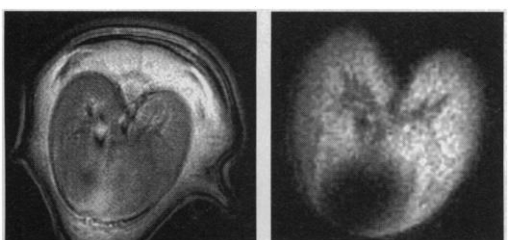
Physics Finds a Middle Ground At Washington Meeting

The 1995 joint meeting of the American Physical Society (APS) and the American Association of Physics Teachers, held from 18 to 21 April in Washington, D.C., surveyed physics on scales ranging from early galaxies to the minute, unobtrusive particles called neutrinos. But highlights came from a middle ground: laboratory studies of polarized atoms, efforts to measure the true strength of gravitation, and a new technique for MRI.

Portrait of a Lung

Magnetic resonance imaging (MRI) has given doctors a way to peer into all kinds of organs, yielding images of living tissues so detailed that they seem to be laid out on a dissecting table. But one part of the body has remained off limits. So MRI devotees had cause for celebration in the waning hours of the APS meeting when Princeton University physicist William Happer unveiled the first magnetic resonance image of the air space within the lungs of a living animal.

Traditional MRI draws a blank inside lungs because the technique maps water molecules in tissues, and the lungs are filled with air, not water. But by replacing the air with an inert gas specially prepared to emit a magnetic resonance signal even stronger than water's, Happer and his colleagues at Princeton, the State University of New York at Stony Brook, and Duke University have turned MRI into a window on the workings of the lung. "It looks very exciting as a research tool," says Gary Fullerton, editor-in-chief of the *Journal of Magnetic Resonance Imaging*, and the researchers think it has clinical promise as well.



View of inner space. MRI with spin-polarized gas *(right)* reveals the lung's air spaces, invisible to conventional MRI *(left)*.

PHOTOS BY DUKE CENTER FOR IN VIVO MICROSCOPY

Ordinary MRI detects water by sensing the magnetic moments, or nuclear spins, of protons in the water molecules. The spins normally are random, but when a powerful magnetic field aligns some of them, their small magnetic moments add up, allowing them to be mapped. Gases, though, are too tenuous to give off a strong signal even in a powerful magnetic field. So Happer and his colleagues set out to "hyperpolarize" a gas, lining up so many of its spins that it gives off a powerful signal in spite of its low density.

Their strategy relies on a technique called optical pumping, which lines up the atomic spins in a gas by exposing it to intense, circularly polarized light from a laser. Inert gases like helium or xenon resist optical pumping, so the group first spin-polarizes a vapor of an alkali metal such as rubidium. Rubidium gas is too hot and toxic for living lungs, but the spin can be transferred to an inert gas simply by mixing it with the rubidium; random collisions of atoms then transfer the polarization.

Two years ago, the Princeton researchers teamed up with medical imagers at Stony Brook to produce an image by infusing spin-polarized xenon into a lung that had been removed from a mouse. Now, in collaboration with the MRI gurus at Duke University's Center for In Vivo Microscopy, they have used spin-polarized helium to extend the work to the lung of a living guinea pig.

The intense polarization of the gas means each image can be made in just a second, compared to minutes for normal MRIs. Because the images show the lung's air sacs and passages, says physicist Alan Johnson, a collaborator at Duke, a string of such images "could essentially make a movie revealing lung function," providing insight into lung diseases like emphysema and asthma. And because xenon dissolves in the blood, the researchers say it could serve as an MRI tracer, highlighting the blood vessels that carry oxygen from the lungs to the heart.

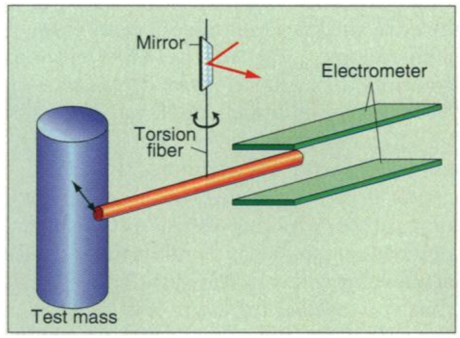
Happer and his colleagues think existing MRI machines could be retrofitted to deliver hyperpolarized gas. But before that can happen, clinical tests in humans are required, and Johnson says eagerly, "I'll probably be the first guinea pig."

–Antonio Regalado

G Whizzes Disagree

There's no force more familiar to human experience than gravity, and few natural quantities have such venerable scientific histories: Physicists have had a good description of its behavior since 1687, thanks to Isaac Newton. But its exact strength is a surprisingly uncertain matter. Although you might expect physicists to argue about the mass of the newly discovered top quark, you wouldn't expect disagreement about "big G"—the gravitational constant that, together with mass and distance, gives the attractive force between two objects.

Think again. At the APS meeting, three groups of physicists from around the world presented new measurements of big G. The results of their experiments, done at standards laboratories that specialize in making precision measurements, differed by as much as 0.6% from the textbook value. That is some 60 times the difference that the predicted experimental errors allow for.



Balance of forces. One experiment measures the electrostatic force needed to resist the gravitational tug of a test mass.

ILLUSTRATION: E. CARROLL SOURCE: FITZGERALD AND ARMSTRONG

What's going on here? "We were hoping some wise person could tell us," implored Winfried Michaelis, a physicist with Physikalisch-Technische Bundesanstalt, the German bureau of standards, who led one experiment. All he and the other G-men could offer by way of explanation is the lack of any theoretical guidance about what the value of G should be and the experimental challenge of measuring a force as feeble as the attraction between laboratory masses. Added to that is the impossibility of shielding an experiment from outside sources of gravitation, said Gabriel Luther of Los Alamos National Laboratory. Luther, whose 1986 value for G (6.6726×10^{-11} m^3/kgs^2) is the current benchmark, says his measurements have been affected by everything from a rising water table to packed bookshelves in an adjacent lab.

Like Luther, the Michaelis group measured G using a variation of a classic torsion balance experiment, in which the gravitational attraction of large stationary masses deflects a light rod suspended by a wire. Yet the group came up with a value of G 0.6% above Luther's. Michaelis, who spent 3 years rethinking every possible source of experimental error, says he stands by his result.

Two other groups were also standing firm—on the other side of the accepted value. Mark Fitzgerald of the Measurement Standards Laboratory of New Zealand and his colleagues came in 0.07% below the standard value with their torsion balance experiment. Back in Germany, Hinrich Meyer's group at the University of Wuppertal ended up 0.06% low using a different system—a pair of pendulums deflected by the gravitational tug of two large masses.

At least one explanation is out. The researchers firmly reject the notion that G could be changing with time or position on the planet. Still, the challenge of pinning down its value remains. The best place to do so, the researchers agreed, would be in orbit, away from Earth's gravity and other confounding signals. But "no one is going to pay for that," says Luther, so he is now remeasuring the constant "for fun" on an arid mesa a thousand feet above the Rio Grande River. Far from traffic and the troublesome water table, the experiment will make two simultaneous measurements of G using different techniques. That, says Luther, should make it the most precise yet.

–A.R.

Edging Toward Supersymmetry

Much of particle physics is in the doldrums. The canceled Superconducting Super Collider will never be more than a hole in the Texas prairie; the Large Hadron Collider at CERN, in Switzerland, won't reach its full energy until well into the next century. But inside tabletop atomic physics devices like the one in Norval Fortson's laboratory at the University of Washington, physics at the frontier is alive and well.

That was Fortson's message at the APS meeting, where he reported that his laboratory had made the most sensitive search yet for an electric dipole in the atom—a tiny separation between its centers of positive and negative charge. The experiment doesn't sound like the stuff of high-energy physics: lining up the magnetic spin axes of mercury atoms, then nudging them with an electric field and probing for the wobble that betrays a dipole. But this wobble, if it appeared, might support a theory called supersymmetry, which many physicists have embraced as their best hope for extending their picture of the forces of nature. "It would be an epoch-making discovery," says theoretical physicist Stephen Barr of the Bartol Research Institute in Newark, Delaware.

So far, though, Fortson and his colleagues Steve Lamoreaux, Blayne Heckel, James Jacobs, and William Klipstein have seen no trace of a wobble. The lack of any dipole larger than 8×10^{-28} centimeters—the current sensitivity of the Washington experiments—"is a soft bound on supersymmetry," says Fortson, who notes that the simplest versions of the theory predict an effect at least 100 times that size. But the dipole could be smaller in other versions of the theory, says Barr, which means that something interesting might be just around the corner.

Supersymmetry creates a single framework for the two basic kinds of particles in nature—force-carrying particles such as photons and "matter" particles such as quarks and electrons—and posits massive, shadowy partners for known particles. These particles would materialize only at energies higher than the largest accelerators today can muster. But quantum mechanics grants even particles that aren't at home at everyday energies a fleeting presence as "virtual particles" that wink in and out of existence. Like ghosts that subtly rearrange a room while no one is looking, the virtual supersymmetric particles would interact with the quarks in an atom's protons and neutrons, leaving a mark in the form of a tiny electric dipole.

Tiny is just what the Washington experiment is designed to see. The latest results, submitted to *Physical Review* A, could reveal a separation of charge so small that "if you took a mercury atom and blew it up to the size of the Earth, that little bit [the dipole] would correspond to a hundredth of an angstrom," says Fortson. Its absence, along with the failure of other experiments to find any dipole in the neutron and the electron, shows that "the simplest [version of the] theory can't be right," says Barr. "I don't want to give the impression that there is some sort of crisis in supersymmetry. But it is extremely interesting for a theorist."

Actually finding a dipole would be still more interesting, of course. Fortson's group and others are promising an even closer search over the next couple of years. Just by probing for the wobble with a laser beam rather than the high-intensity lamp of their current apparatus, for instance, Fortson thinks his group can boost the sensitivity of their experiment by a factor of 10. "We have a lot of room for growth," he says—a claim not many experimental physicists can make these days.

–Tim Appenzeller

PLANT BIOLOGY

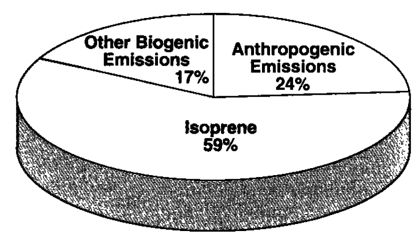
A Clearer View of Why Plants Make Haze

Australia's Blue Mountains. Virginia's Blue Ridge. Jamaica's Blue Mountain Peak. Places all over the world have acquired names evoking the bluish haze that hangs over wooded hills in summer. But what makes them hazy? In 1960, botanist F. W. Went suggested that simple hydrocarbon gases given off by trees were responsible, a phenomenon that 20 years later prompted the Reagan Administration to blame "killer trees" for air pollution. But the scientific story behind the emissions—and the implications for air quality—have remained, well, hazy.

An experiment reported in last week's issue of *Nature* dispels some of the haze by offering an answer to one question: Why do plants go to the trouble of producing it? The research implies that plants produce one major haze ingredient, isoprene, as a strategy for coping with heat. And that, together with recent evidence that these hydrocarbons are far more abundant than was thought, could change researchers' picture of the less benign haze that forms over urban and even rural areas on hot, sunny days. By understanding when and why plants give off hydrocarbons, explains Chris Geron, who does atmospheric modeling for the Environmental Protection Agency (EPA) in Research Triangle Park, North Carolina, "we can better understand the impact [of plant compounds] on our models of air quality."

Plant hydrocarbons, innocuous or even appealing on their own (the scent of a Christmas tree comes from one), are ingredients in photochemical smog. Along with hydrocarbons from cars and backyard grills, they combine with nitrogen oxides from combustion in engines and industry to generate low-level ozone—an irritant to lungs and to the plants themselves. "When plants did this 100 years ago, ozone formation was [probably] not being catalyzed," says Ray Fall, a biochemist at the University of Colorado, Boulder. "Now it triggers ozone."

Daily Hydrocarbon Emissions in the Atlanta Area



SOURCE: W. L. CHAMEIDES AND CARLOS CARDELINO

Recently, Geron and other researchers have come to realize just how large a role plants can play in ozone formation. Geron notes that the latest EPA inventories put emissions of isoprene at levels three to five times higher than previous estimates. One study of all hydrocarbon emissions in the Atlanta area showed that plants were by far the largest contributor (see graph), with isoprene topping the charts.

But researchers have been at a loss to say why plants should produce isoprene in such quantities. Doing so, after all, is an expensive proposition for plants, with no apparent function. Isoprene production alone typically siphons off 2% of the carbon fixed through photosynthesis, carbon that could otherwise be converted into sugars. "It's a