command the millions of dollars needed to carry it out. The doubters, however, made some of their peers impatient.

As Montana State's Ivie said: "You've got to get beyond the mindset of 'I can do this with a hammer and a hammock.'" Added Rita Colwell: "What we have in this room is a historic gathering to deal with possibly the most important biological problem there is. We need to do this right. If we were astrophysicists or a group of astronomers, we'd be talking about the real importance and not nickel-and-diming ourselves to death."

As those in the field start to get used to thinking more about this very big picture, one question that quickly arises is where in that picture the systematists fit. There are at least two divergent—and possibly conflicting—views of their role. Those enamored of ATBIs need the expertise of the systematics community to identify all species at a given site. But systematists have other ideas. Having recently escaped status as mere list-makers and acquired a new role as decipherers of phylogenetics, or evolutionary relationships, the systematists are wary of being roped into a handmaiden role. "Where the conflict is is where Dan [Janzen] wants his list of names," says Joel Cracraft, bird systematist at the American Museum of Natural History, "and we're saying we can give you so much more, the predictive power of phylogenetics."

This predictive power, systematists say, could, for example, allow researchers to locate natural products with commercial potential, such as pharmaceuticals, much more rapidly. With such promise in mind, systematists have devised their own initiative known as Systematics Agenda 2000, which will present its preliminary plans next month. Rather than identifying all the species in a given locale, they aim to understand the phylogenetics of the world's biota, an agenda that would require funding in the billions of dollars. And while some stressed the complementary goals of ATBIs and Systematics Agenda 2000, others predicted an intensifying struggle between them and other biodiversity initiatives for funding and for trained researchers.

Despite the clashing of agendas and the many unsolved problems, both technical and sociological, the general feeling at the NSF workshop was one of excitement: a field finding itself on the brink of major change. Mobilizing its troops armed with nets and jars and bags, this biological community seems prepared to make its move into big science, garnering hithero unheard-of amounts of money and personnel to take on the awesome task of knowing—and saving—the world's biota.

–Carol Kaesuk Yoon

Carol Kaesuk Yoon is a science writer based in Ithaca, New York.

PHYSICS

Practicing the Poor Man's Brand of Particle Physics

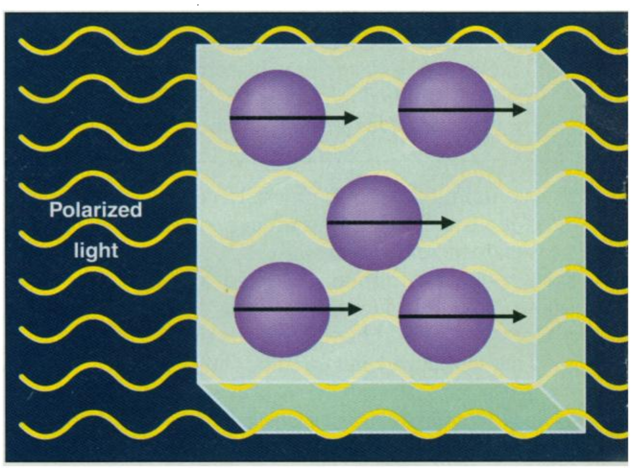
In an age when particle physics is spawning industrial-scale, money-hungry monsters of experiments, there is a low-budget alternative. "We're the poor man's high-energy physics," quipped physicist Steve Lamoreaux at April's American Physical Society (APS) meeting in Washington, D.C. The full-priced version goes after the fundamental nature of matter using miles-long accelerator rings to smash together particles and condominium-sized detectors to analyze the subatomic spray that results. But Lamoreaux and his colleagues at the University of Washington, along with a handful of other groups around the country, are hoping to extract equally significant clues from tabletop experiments that search for tiny wobbles in atoms exposed to electric fields.

At the APS meeting, Lamoreaux announced that he, group leader Norval Fortson, and their colleagues had achieved unprecedented sensitivity in their quest for these wobbles, which would betray an electrical asymmetry, or dipole, in particles making up the atoms. The researchers can now detect an offset of less than 10^{-26} centimeter between an atom's centers of positive and negative charge. And that sensitivity brings within reach a measurement that could change the future direction of physics. Within a couple of years, the Washington experiment and those of the competing groups should reach a verdict on one prediction of supersymmetry, an as-yet-untested theory that is physicists' current best hope for extending their understanding of particles and forces.

The entrenched, working road map to the subatomic world, known as the standard model, predicts an electric dipole so small as to be out of reach of experiment. But supersymmetry offers some hope. It predicts an electric dipole of less than 10^{-27} centimeter, a distance so small that if you blew up an atom to the size of the earth, the offset would amount to less than the width of a human hair. If the tabletop experimenters do detect this dipole, they will have given their colleagues one of the first glimpses of physics beyond the standard model. And, as a bonus, an electric dipole would provide the first clearcut evidence of something physicists have been seeking for even longer: an arrow of time in the subatomic realm—some way in which subatomic processes can tell forward from backward in time.

"Finding [a dipole moment] would be epoch-making," says theorist Stephen Barr of the Bartol Research Institute in Newark, Delaware. "It's bound to be new physics." Its discovery, Barr and other theorists point out, wouldn't undercut the Superconducting Super Collider (SSC) and other big accelerators, which are also questing for physics beyond the standard model. Only with a giant accelerator would it be possible, for example, to find the array of new particles predicted by supersymmetry or track down clues to the baffling array of masses seen in known particles. But Nobel laureate Steven Weinberg of the University of Texas at Austin says the tabletop experiments are worthy complements to the big-physics studies: "Work on the electric dipole is as interesting to particle physicists as anything else in the field."

The dipole search grew out of earlier experiments, done not with whole atoms but with neutrons, that sought breaks in the fundamental symmetries of nature. The earliest work, in the 1950s, sought a right-left spatial asymmetry, or "parity violation," in the neutrons. Nothing turned up, though parity violation was soon discovered in other forms. Then it became clear that a more profound consequence of a dipole would be a violation of symmetry in time—an arrow of time. Other parts of the universe—the human psyche, the expanding cosmos, the universal increase in entropy—seem to recognize an arrow of time. Puzzlingly, though, the subatomic world



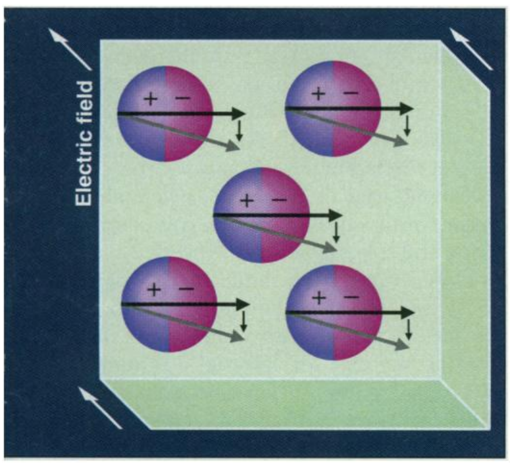
A telltale wobble. In one tabletop physics strategy, polarized light aligns the magnetic spin axes in a set of atoms *(above)*; then an electric field is applied. If the atoms' centers of positive and negative charge are offset, creating a dipole, the atoms will precess around their axes *(right)*.

generally seems unable to tell forward in time from backward: Nearly every collision or subatomic decay would look identical if you played it in reverse.

The search for a subatomic arrow of time got a boost in the mid 1960s, when researchers found hints of time asymmetry in one very rare subatomic process, the decay of a K meson. That made them think they might see the effect somewhere else. "It's like a disease," says theorist Barr. "If it shows up in one place, it should infect others." And one sign of time asymmetry would be an electric dipole, because any particle carrying a dipole would behave differently if time ran backward.

The key to this asymmetry is the relation of the electric dipole to the particle's magnetic axis. The magnetic axis, like the spin of a top, would change direction if time ran backward. An electric dipole, on the other hand, would keep the same orientation. As a result, a particle carrying both an electric dipole and a magnetic spin axis would look different when time is reversed: The magnetic axis would flip, so that if the two axes started out aligned, for example, they would end up pointing in opposite directions.

In spite of the hopes, the early searches for an electric dipole in neutrons turned up nothing. But improved experimental technology and new developments in theory have pushed the search to the forefront again. Unanswered questions in the standard model, which took shape in the 1970s, have led physicists to



D. DEFRANCESCO

look for wider-reaching and deeper models—and a leading contender is supersymmetry. Supersymmetry links three of the four forces of nature, the weak and strong nuclear forces and electromagnetism. (It will take an even more comprehensive theory to fold in gravity.) It predicts a much larger dipole in the electron and the neutron than the standard model does. As supersymmetry has gained popularity, mainly because of its pleasing mathematical consistency, so has the notion of testing it through tabletop physics.

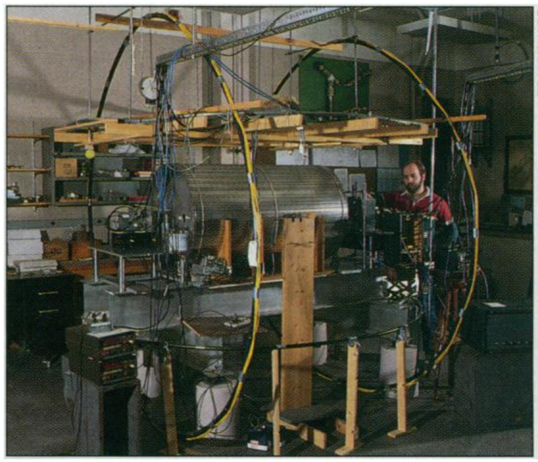
A thorough test means looking for a dipole in electrons as well as neutrons, because supersymmetry makes different predictions for each. Such measurements once seemed out of the question for electrons, since an electric field applied to a collection of electrons would pull them all to one end of the apparatus. But in 1964, P.G.H. Sanders of Brandeis University predicted that any dipole in the electrons associated with an atom should show up as an amplified dipole of the entire atom—and, being neutral, atoms are otherwise unaffected by an electric field. And now improvements in laser and computer technology are enabling researchers to capitalize on that insight and look for an electric dipole in whole atoms, says Amherst physicist Larry Hunter.

Hunter's group is pursuing the quest by shining light into a vapor of cesium atoms. First, he says, he and his colleagues line up the magnetic axes of the atoms with a technique called "optical pumping"—beaming in light polarized in just the right orientation. Then the researchers apply an electric field at a different orientation. If the atoms have a dipole moment, the electric field should exert a force, making the magnetic spin axes "precess," much as a slowing top starts turning slow circles around its spin axis as gravity starts to drag it down.

Hunter tries to detect this precession, again with light beams polarized in the direction of spin. If the atoms are precessing, the intensity of the reflected light should vary at the frequency of the precession—a clue to the magnitude of the dipole. To screen out the effect of stray magnetic fields, which can confound the measurements by causing the same kind of precession, Hunter makes the measurements with several vapor-filled cells, using electric fields of different orientations. Gene Commins at the University of California, Berkeley, follows a similar strategy to search for a dipole in thallium atoms.

Meanwhile, Fortson and his group at the University of Washington are taking a different tack to try and evade the effects of stray fields. He and his colleagues are using a scheme like Hunter's to look for precession in mercury atoms. But since measurable electron dipoles should show up only in atoms with unpaired electrons and mercury's electrons are all paired up, any dipole discovered in the mercury would really reflect a dipole in the nuclear particles—the protons and neutrons. That's a much weaker effect, but it's less likely to be contaminated by unwanted magnetic fields, says Fortson. Finally, a group at Yale, headed by Edward Hinds, is experimenting with a molecule, thallium fluoride, which should exhibit an even bigger amplification of the electron dipole than isolated atoms do.

These groups plan to improve their sensitivity by a factor of 10 or more in the coming years. If no dipole turns up by then, says Hunter, things will get "uncomfortable," for supersymmetry, and perhaps more comfortable for alternative theories. And if the research does yield evidence of a dipole, the discovery could turn the physics world on its ear—providing the results can gain acceptance, says Commins. "If we get a positive result, everyone in the world would jump on us and say, 'Why didn't you do this? Why didn't you do that?' " he says. "My goal is to design an experiment that I can be absolutely sure of."



FRANK WARD

Small science. Could clues to supersymmetry emerge from an apparatus like this one, at Amherst College?

Even then the results won't substitute for the work going on at the big accelerators. Bartol theorist Barr, though entranced with the tabletop experiments, still promotes the SSC. "There are features in the standard model that cry out for an explanation," he says. "The mysteries of physics will not unravel" with atomic experiments alone, he says. Even if the experiments do reveal an electric dipole of the size predicted by supersymmetry, he says, physicists would still want to round up the host of new particles the theory predicts.

Although atomic physics can't provide all the answers, the tabletop experimenters aren't tempted to join the industrial-scale collaborations of high-energy physics. "Particle physics really is the most interesting sub-branch for producing new insight," says Hunter, who has worked in the field. "But I realized I didn't find it satisfying to work as part of large collaborations—doing one small piece of a huge project."

Berkeley's Commins agrees. "I like working on this style of experiment—it can be done with one or two grad students and a postdoc and relatively little money.... It's on a human scale." And though that scale may seem small next to a particle accelerator, in some ways the tabletop experiments offer broader horizons, says Lamoreaux. "You can only design an accelerator so big," he says, "but you can keep doing more and more precise measurements."

–Faye Flam