Counting Creatures Great and Small

A unique workshop brought together 45 of the world's biodiversity experts to discuss how to identify every single species in a particular plot of land–something that's never been done

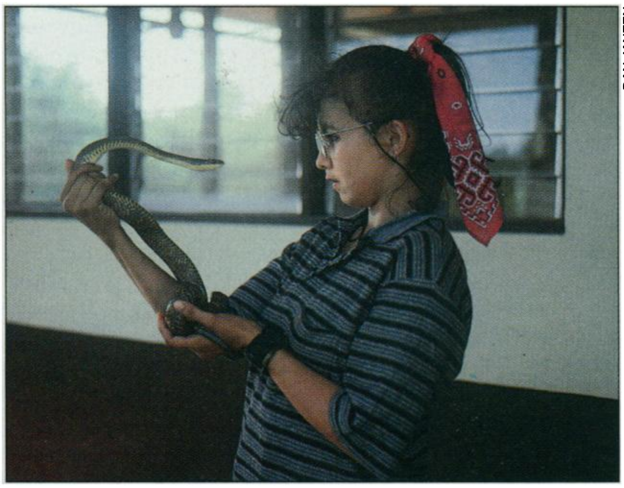
Bill Clinton's new secretary of the interior, Bruce Babbitt, recently proposed the creation of the United States' first National Biological Survey, appointing Thomas Lovejoy of the Smithsonian Institution, an eminent conservation biologist, as science adviser charged with setting up the survey. In this era of green consciousness, Babbitt's announcement was greeted with enthusiasm. But once the cheering stopped, some hard questions began to resonate. First and foremost: What is the survey? Important as the question is, there aren't yet many clear answers. At first, says Lovejoy, efforts will be devoted simply to consolidating information about the nation's ecosystems from various agencies at the Department of the Interior as well as from other departments.

That's a big job, but it's likely to be only a starting point. In time, expert observers say, the survey will need to turn not only to information held by other nongovernmental agencies, like the Nature Conservancy, but also to the task of directly acquiring new data. Specifically, as the unit's name suggests, it may well undertake detailed surveys in specific locales. Such inventories, once scorned by researchers as being of dubious scientific merit, have recently begun gaining scientific legitimacy. And because they can identify areas where biological diversity is threatened, they are considered a first step toward protecting the number and range of species around the world.

In the latest sign of this new era of scientific respectability for biological surveys, 45 of the world's leading systematists and biodiversity experts gathered earlier this month at an unusual workshop at the University of Pennsylvania, which was sponsored by the National Science Foundation. The select group of 45 came together to discuss how to carry out the world's very first All Taxa Biodiversity Inventory (ATBI), an exhaustive survey of all the various kinds of organisms in a single restricted area.

How, they asked, could researchers survey absolutely every species of organism in, say, 200 square miles of tropical rain forest? By creating what they called a known biological universe, scientists hope to turn wilderness into a resource, promoting conservation by providing the necessary information for the management and utilization of its riches. The workshop's organizers, tropical ecologists Dan Janzen and Winnie Hallwachs of the University of Pennsylvania, expressed hope that future users of an all-taxa inventory might extend far beyond researchers to include the "ecotourism" industry and even schoolchildren.

But those dreams are far off, since, as participants in the workshop were well aware, no ATBI has ever been carried out. As Mike A. Ivie, a beetle specialist from Montana State University and a workshop participant, put it, "There is no place on Earth—none—where the entire biota is known." Others were equally emphatic. "We're talking about doing a new kind of biology," says Robert K. Colwell, an evolutionary ecologist at the University of Connecticut. "Like knowing for the first time what the face of the moon looks like, this is the first time we'd know what a whole tropical forest really looks like, what's in it."



DAN JANZEN

Getting to know you. A student in Costa Rica learns how to identify snakes as part of a biodiversity survey.

Yet knowing what the rain forest—or any other ecosystem, for that matter—"really looks like" is bound to be a Herculean task. It's difficult enough to identify all the birds flying over head, the beetles tumbling through the canopy, or the myriad plants that make up the forest itself. But add to that the thousands of unidentified species of bacteria that are squirming through every gram of soil, not to mention viruses, fungi, and other poorly known groups, and the dimensions of the never-before-done job begin to come into view.

In defining strategies for mapping this terra incognita, workshop participants considered everything from technique (how do you collect and preserve a bird as well as its gut fauna, its parasites, and their parasites?) to information technologies (how do you store and manipulate this flood of new data?). In addition to such predictable problems, researchers raised issues many of us would never think of: How can a collector go to the bathroom without introducing new species to the site? Beyond those issues, they had to deal with tension over the role of systematists, who, having recently shed a long-held reputation for being scientific "stamp collectors"—mere makers of lists of species names—want to ensure that efforts to inventory biodiversity do not force them back into that role.

The importance of the systematists came quickly to the fore, as the 45 researchers confronted a difficulty that was raised again and again during the 3-day gathering: the paucity of specialists who can decipher even the knowns from the unknowns in the expected flood of collected species from an ATBI. Many taxa, or groups of organisms, are currently scholarly "orphans," having no researchers dedicated to their study. This dearth of scientific expertise would be a roadblock not only to ATBIs but to any large-scale attempt to understand global biodiversity.

The lack of trained researchers is a particularly sharp concern for the many poorly known groups, like fungi and bacteria, that are rarely considered by the lay public but in fact make up the bulk of the world's biodiversity. According to Rita Colwell, a microbial systematist at the University of Maryland, there are so many microbes out there and so many are undescribed that, "in 2 weeks in the field, we can get enough samples to deal with for 10 years." James M. Tiedje, a microbial ecologist at Michigan State University, says DNA-DNA hybridization studies have indicated that there may be as many as 10,000 species of bacteria in a single gram of temperate forest soil. Yet only about 3000 species of bacteria have actually been named, says Tiedje, starkly outlining the dimensions of the problem.

Bacteria are far from being the only multitudinous, little-studied organisms in the forest. Virginia Ferris, a nematologist at Purdue University, says that even in temperate for-

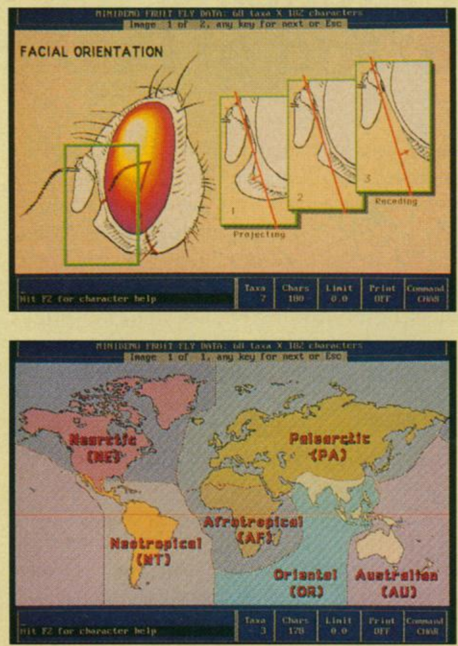
Getting the Bugs Into the Program

For more than a century, museum specimens were restricted to carrying only the data that would fit on their tiny labels. Worse, any such information, meticulously organized with specimens in their mothballed boxes or formaldehyde-filled jars, remained inaccessible behind locked doors.

Now all that is beginning to change, as specialists in informatics work with biologists to come up with innovative ways of managing the mountain of data already in museums—as well as the cascade of new information from biosurveys that will soon be under way (see main story).

The promise of these new technologies is that researchers will be able to see everything known about a specimen, from the location where it was collected, to the DNA sequence of its mitochondrial genome, to a digitized photo of the specimen itself, just by passing a reader over the specimen's bar-coded identity.

That promise is yet to be realized, but new information technologies are already in place, ranging from expert systems (programs that allow a nonexpert to identify beetle grubs, fruit flies, and weeds), to collection databases complete with digitized images of specimens.



BRITT GRISWOLD/SYSTEMATIC ENTOMOLOGY LAB

Fly screens. Two displays from a USDA expert system for fruit fly identification.

Expert systems, like the one being developed for fruit flies atthe United States Department of Agriculture's Systematic Entomology Laboratory by F. Christian Thompson and his colleagues, surpass traditional written methods of identification, which are larded with references to obscure parts of the organism known only to specialists. In a computer-based expert system, the task is simplified by detailed drawings of key anatomical characteristics provided onscreen. The user can browse among them, choosing the information he or she will use to identify the find, a design that greatly increases the chances that someone who is not a full-fledged systematist can make a successful identification.

Most biodiversity databases are still in the early stages of development, but researchers generally seem to agree that the most advanced integrated biological database is Australia's Environmental Resources Information Network (ERIN). ERIN contains, among other things, species distribution data, vegetation type data, and climate data. As a result, it can predict, for example, where new populations of an endangered species with a limited known range might be expected to be found or what regions are likely to become trouble spots of endangered species in the near future, functions like those proposed for the new U.S. National Biological Survey.

But useful as it is, ERIN is not being imitated all over the world. Indeed, less than 1% of the information in the world's museums is actually databased, according to Ebbe S. Nielsen, director of the Australian National Insect Collection. And that isn't the only obstacle. Jim Beach, museum data administrator at Harvard University, says even databased information is often inaccessible to users outside a particular museum or university. In the absence of guidelines for storing and organizing biodiversity information, networking to manipulate or combine information from more than one database quickly becomes prohibitively labor-intensive.

Those problems won't be solved anytime soon. Nevertheless, it is clear that for biodiversity the future is electronic.

–C.Y.

ests, sampling to a depth of just 15 centimeters, one can find 2 to 6 million nematodes per square meter, with as many as 200 species present—most of then unnamed and unknown. "We'll be lucky," says Ferris, "if even 1% of what we find have been described."

That sounds bad, but for some of the least-known groups, the situation is even worse. Diana Lipscomb, a protist specialist at George Washington University, told workshop participants that for some groups, there aren't even any reference collections to which new field collections can be compared for identification. "The protist collection at the Smithsonian," she said, "is two slide boxes and you have to ask around to find out which drawer it's been stuck in. There is no curator. There is no network of people to tap into."

The ecologists, conservation biologists, and systematists present at the workshop seemed to agree that for these neglected groups, the only answer is somehow to increase the ranks of the systematists. While researchers agreed that promising students must be recruited into the field, some pointed out that systematics has provided so few jobs in recent years that many researchers have left the field. More funding, they said, and the creation of new positions might pull these scientists back into the work for which they were trained.

Even if there were enough trained specialists to begin conducting ATBI's tomorrow, they would have to solve a host of technical problems—intertwined with changes in mindset that the field is now undergoing. For example, a central technical problem that came up repeatedly in Philadelphia is the best way of storing and accessing the mass of data accumulated in such a biosurvey (see sidebar). Informatics specialists at the meeting said many new information technologies are now being tried by universities and museums. Nonetheless, in a field where researchers have tended to work quite independently, there is no standard for a large, interactive network of biodiversity data.

In order to develop such a network, researchers in biodiversity will have to learn to handle the compromises and conflicts inherent in massive collaborations—much as physicists do in work on, say, the Superconducting Super Collider. That means changes in technique. Says Terry L. Yates, curator of mammals at the University of New Mexico, "You can't collect your spiders the way you always have and take them back home." One challenge will be separating and cataloging organisms that live together. As Yates puts it, "You'll have to get the viruses off the spiders and everything else before you do that." As a first step toward developing these new techniques, researchers at the workshop began what promises to be an ongoing dialogue about what methods of preservation for a large animal or plant might facilitate its being resampled later for smaller creatures.

As their field is energized by large, new, policy-relevant projects, biodiversity experts aren't just having to rethink their techniques. They're also having to think a whole lot bigger. Some researchers at the workshop, for example, used to making do with very limited funding, argued over particular costs, expressing skepticism that an ATBI could 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

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PHYSICS

Practicing the Poor Man's Brand of Particle Physics

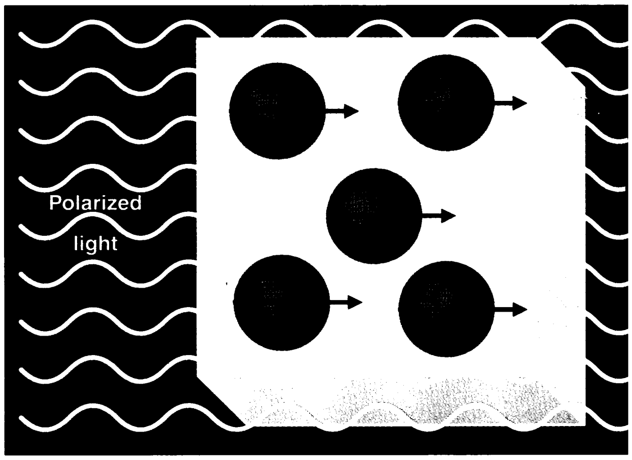
In an age when particle physics is spawning industrial-scale, money-hungry monsters of experiments, there is a low-budget alternative. "We're the poor man's high-energy physics," quipped physicist Steve Lamoreaux at April's American Physical Society (APS) meeting in Washington, D.C. The full-priced version 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)*.