An Institute for Planet Earth

In a bold, contentious move, Columbia University is linking its renowned earth science faculty with biologists and social scientists to study the planet's future

PALISADES, NEW YORK—For half a century, the Lamont-Doherty Earth Observatory, perhaps the world's premier center for earth science research, has perched on the cliffs here, overlooking the Hudson River 15 kilometers north of New York City. In a setting that some have likened to a monastery, its community of just over 100 scientists has been pleasantly isolated for most of that time—even from their host university, Columbia, a world away in upper Manhattan.

In this secluded environment, Lamont researchers have built a reputation for excellence—making discoveries about the spreading of the ocean floor that laid the groundwork for plate tectonics, tracing global ocean currents, and studying ancient climate changes. More recently, they developed the first computer simulation that could correctly predict El Niño and discovered that Earth's inner core rotates independently from the rest of the planet.

But now, as it nears its 50th birthday in December 1999, the monastery is being opened to the world. Lamont-Doherty is the nucleus of Columbia's new Earth Institute, the university's effort to link the earth sciences with biology and social science. University leaders are trying to connect the observatory's faculty members with researchers "across the river" on the main campus to address crucial environmental questions such as the human and economic effects of global warming and loss of biodiversity—and, they hope, to capture a share of the growing federal funding for global change research.

Other universities are watching with interest. Observers say Columbia's efforts to develop a global change program, although not unique, are more ambitious than anything other institutions have tried. "I don't know of any other university that is consciously trying to bring about as much activity as Columbia is," says Ralph Cicerone, an atmospheric chemist who is dean of the college of physical sciences at the University of California, Irvine. Since 1994, Columbia has launched 10 new programs or centers as part of the Earth Institute (see table). They range from the takeover of Biosphere 2, the sealed greenhouse in Arizona, to the Earth Policy Center, which links earth and social scientists.

And next month the university will break ground on Lamont's campus for a $10 million building to house the fledgling International Research Institute for Seasonal to Interannual Climate Prediction (IRI), a collaboration with the Scripps Institution of Oceanography and the National Oceanic and Atmospheric Administration. The institute will eventually host about 40 staff scientists and 40 visitors from around the world—geophysicists, anthropologists, and others—who will work to predict the human consequences of climate events like El Niño. "It's a very unusual and courageous move on their part to bring so many intellectual disciplines together," says Robert Corell, the head of the National Science Foundation's geosciences directorate.

DAVID DICK / LDEO

Opening to the world. Lamont-Doherty Earth Observatory's geoscience library.

The scale of the effort isn't the only daunting thing about it. "Our first year out of the blocks has not been easy," acknowledges Columbia Vice Provost Michael Crow, one of the driving forces behind the Earth Institute. Many researchers at Lamont are wary of the project. "The emphasis is on societal relevance," says one longtime Lamont researcher. "For a lot of solid earth geophysics, it's hard to capture that."

The early days of the Earth Institute have also exposed cultural rifts—differences in views about how to conduct an experiment and when to publish results—between fields that are supposed to collaborate, such as atmospheric chemistry and ecology. And some faculty members say that the institute's controversial director, Peter Eisenberger, has worsened the tensions by favoring some fields and neglecting others. One leading researcher is leaving, another has threatened to do so, and talk of shake-ups is in the air. But Crow says no one expected the changes to be easy or fast. "We're patient," he says. "We're taking a longer view."

Connecting different worlds

The roots of the Earth Institute go back nearly 7 years, to when Crow came to Columbia from Iowa State University in Ames to work as a consultant to Gordon Eaton, Lamont's director at the time. "There was a separation between this community of exceptional scholars and the rest of the university," says Crow. "Even though they were succeeding on their own," he says, he and others wanted to draw Lamont into the evolution of the university as a whole.

About the same time, he says, "everyone was starting to realize that the Earth was an integrated problem—that you had to take the physical, natural, and social sciences together to address the bolder concept of how to better manage the Earth." Eaton, Crow, and other university leaders saw that Columbia had many of the basic building blocks in place—respected schools of public policy, public health, and medicine, as well as earth science. The Earth Institute's role, says Eisenberger, is "to add a catalytic piece" that brings the different disciplines together.

It seemed a rich vein both intellectually and financially—federal funding for global change research is $1.9 billion this year—and so Columbia launched a "global systems initiative," which began funding pilot interdisciplinary projects. In 1995, Eaton resigned to head the U.S. Geological Survey. Columbia then hired Eisenberger, a physicist who had been head of the Materials Institute at Princeton University, to be both director of Lamont and vice provost in charge of the newly named Earth Institute.

So far, Columbia has committed more than $10 million in new funds to provide seed grants for research and to hire a dozen new faculty members—and as many as 20 more may join them, Crow says. Most of those new hires, Eisenberger says, will hold joint appointments in two departments or schools and will strengthen areas in which Columbia is weaker, especially in ecology and other biological sciences.

At Lamont, posters advertising a seminar on biodiversity and a workshop on "climate impact assessment" hang next to an announcement of a lecture on ocean geochemistry. And the monastery is accepting new members from different traditions. Plant physiologist Kevin Griffin, who arrived from the Desert Research

A Mini-Earth Struggles for Respectability

ORACLE, ARIZONA—The original planners of Biosphere 2, the giant greenhouse in the Arizona desert, hoped to build a microcosm of Earth, which they called Biosphere 1. Now the facility's current manager, Columbia University, is attempting a seemingly more modest goal: creating a microcosm of the university's Earth Institute—a research and teaching facility focused on the science of global change (see main text).

The new goal may be no less ambitious than the old one, however. Technical difficulties and disagreements over how to use the facility have stalled progress. Since Columbia took over on 1 January 1996, published research has been sparse, and several scientists have quit Biosphere in frustration, including Wallace Broecker, a geochemist at Columbia who forged the first ties between Biosphere 2 and the university.

Now Broecker and others see encouraging signs. Several papers on Biosphere research are in press, and an experiment in the 3.8-million-liter "ocean" made a splash at a recent meeting. The study showed how the changes in ocean carbonate concentration expected to result from rising atmospheric carbon dioxide can damage corals (*Science*, 13 February, p. 989). And a long-planned experiment on the effects of carbon dioxide on trees is getting started this month—one of more than a dozen projects currently under way. "Finally, they've sort of turned the corner," says Broecker. "It bottomed out, and it's started back up."

It's not the first time the facility has been down and bounced back. Financed by Texas billionaire Edward Bass, the 1.3-hectare, $200 million greenhouse was originally designed as a new-age experiment: a sealed, self-sufficient miniecosystem capable of supporting eight people and thousands of animals and plants for 2 years. Launched in 1991 with much fanfare, the project became the butt of jokes as oxygen levels declined and food production dwindled. In 1993, the biospherians asked Broecker for help, and he and graduate student Jeff Severinghaus established that bacteria in the rich soils were consuming more oxygen than expected.

BIOSPHERE 2 CENTER

C. ALLAN MORGAN / BIOSPHERE 2 CENTER

Capricious beauty. Biosphere 2, which contains multiple ecosystems, including an "ocean," has been hard to tame for rigorous research.

Broecker says his visit to Biosphere convinced him that the sealed environment could be a boon to geochemical research. After a second attempt at colonization was aborted and the project went into receivership, Broecker and Columbia Vice Provost Michael Crow helped negotiate an arrangement with Bass, who gave Columbia a $40 million grant to run the facility for 5 years. At the end of that time, the university can give it back to Bass, extend the lease, or purchase the facility and 100 surrounding hectares for $1 million.

Putting Biosphere's potential to use proved more difficult than expected, however. Broecker had envisioned long-term studies of how large plants respond to varying carbon dioxide levels. Ecologists, on the other hand, wanted to study the changes in biodiversity as the miniecosystems evolved. To Broecker, their projects lacked rigor. "One of [the proposed ecology] experiments was to infest the thing with bugs, randomly, and let it run a year, and then kill all the bugs and let it run another year," he says. "Another was to burn half of the rainforest." In December 1996, he quit as science director, frustrated by the lack of progress.

But Joseph Berry, a plant biologist at the Carnegie Institution of Washington who heads the scientific advisory committee, says progress had to be slow. "The facility itself was not designed for science," he says. Before experiments could get under way, researchers had to collect basic but crucial information on gas flow, soil composition, and temperature fluctuations.

Now that new monitoring systems are in place and researchers have a better understanding of the system's caprices, one of the experiments Broecker envisioned is finally starting. Researchers will plant fast-growing cottonwood trees in a 0.22-hectare enclosure that has been sealed off from the rest of Biosphere 2 and subdivided, allowing the team to observe how the trees respond to varying carbon dioxide and temperature levels. Other scientists are beginning experiments on the flux of nitrous oxide from the soil to the atmosphere and how plants adapt to ultraviolet light.

Watching and taking part in these projects are students in the "Earth semester" that Columbia hosts at Biosphere 2—just over 50 of them this spring. But it's harder to mesh research with Biosphere's third role, as a tourist attraction. The visitors, who pay $12.95 per adult, provide critical support for the facility, but its scientific charms are not always crowd pleasers.

The "ocean," for example, isn't much to look at—a few small fishes and corals in water stained yellow-green by a dissolved nitrogen compound. The glass roof blocks the ultraviolet light that would normally break the compound down. Biosphere management has decided that the display should be more attractive. So researchers are going to filter the nitrogen out of the water, move rocks and corals so they are nearer the viewing windows, and restock the ocean with fish—including some small sharks. Marine biologist Marlin Atkinson of the University of Hawaii, Manoa, insists that such changes won't interfere with research: "We're going to introduce them in an experimental way."

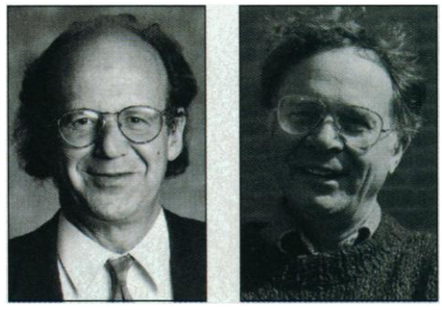
Whether Biosphere can ever be turned into a well-controlled laboratory still isn't clear, however. Temperatures near the ceiling are often more than 20 degrees higher than on the ground, killing the tops of trees, and carbon dioxide still fluctuates wildly every day. Until those problems are smoothed out, it will be difficult to attract the critical mass of scientists needed to make research at Biosphere 2 thrive, says Bruno Marino of Harvard University, a former science director under Bass and a member of the science advisory committee. Deputy director Lisa Graumlich is not worried, however. With visiting researchers from Columbia and elsewhere, "we're at about half critical mass," she says. "But it's an exponential process ... which means tomorrow, we're essentially there." –G.V.

Institute at the University of Arizona last summer, is the first biologist to set up shop on the Lamont campus—in a building where most of the occupants study earthquakes.

Griffin is collaborating with Lamont scientists to see how fossil plants might be used to reconstruct past climates and to analyze how the enzymes in living plants respond to different temperatures and carbon dioxide levels—conditions like those predicted by Lamont's climate modelers for a future greenhouse world. He is also collaborating with researchers from the Carnegie Institution of Washington, the paper manufacturer Westvaco, and Biosphere 2 to study the effects of changing carbon dioxide on cottonwood trees in Columbia's first large experiment at Biosphere 2. Griffin says he does not feel isolated or out of place at Lamont: "It is not hard to convince people that what I do is important to what they do and vice versa."

But not every effort to collaborate across disciplines starts smoothly. Shouting matches broke out between geochemists and ecologists during some of the meetings to set research priorities at Biosphere 2 in the months following Columbia's takeover in 1996, says Crow (see sidebar). And even when collaborators agree on a project, different work habits can lead to tensions. As Crow puts it, "social scientists will go 3 years without publishing, while natural scientists want to publish 5 papers a year."

Even so, several projects have already paid off. One is an IRI-sponsored collaboration between Lamont climate scientists Mark Cane and Stephen Zebiak—two of the first to predict an El Niño event successfully—and Columbia anthropologist Kenneth Broad to develop El Niño warnings tailored to the South American fishing industry. During an El Niño, waters off the coast of Peru become warmer than normal, which disrupts the upwelling of cool, nutrient-rich waters. Food becomes scarce for fish, including anchovy, sardines, and mackerel, affecting their migration and reproduction. The combination of overfishing and a strong El Niño in 1972 caused the anchovy fishery to collapse.



JEAN MIELE / LDEO PHOTO FILE

LDEO PHOTO FILE

Earthly powers. Earth Institute director Peter Eisenberger *(left)* and noted geochemist Wallace Broecker don't see eye to eye.

The researchers wanted to see if they could develop predictions that could help prevent another crash. To make their model "actually useful" instead of "theoretically useful," Zebiak says, the collaboration is learning exactly how its forecasts of ocean surface temperatures correspond to fish migration patterns, as well as how groups from fishers to factory owners react to the forecast information.

But now the team has run into another problem: where to publish the work. "It's not groundbreaking anthropology," says Broad, and it doesn't really fit into a geophysical journal. "It's a risk for a nontenured person to go into this," he says, "because they'll come up for tenure in their department, and [evaluators] are going to look for publications in the top journals in their field" rather than in less familiar cross-disciplinary publications.

Seismic strains

Not all the stresses at the Earth Institute are intrinsic to cross-disciplinary work, however. Some scientists complain that a few areas are getting too much attention, while disciplines in which Lamont is traditionally strong are being slighted. "I think that people who do traditional work have gotten the idea that [Eisenberger] is never going to put any more resources into fields like petrology—and that's about half of Lamont," says Lamont geochemist Wallace Broecker, an outspoken critic. "He's really crippled the morale."

Others complain that study of the economic impacts of global change has dominated the Earth Institute's agenda. Indeed, two of the institute's units are focused on economics and applied mathematics. Both are headed by mathematical economist Graciela Chichilnisky, who is also co-chair of the planning committee in charge of setting the institute's intellectual agenda. "Mr. Eisenberger is very keen about the economic side of using the basic science," says Lamont's associate director, oceanographer Taro Takahashi, but he says most scientists at Lamont are more interested in humanitarian applications for their research, such as arms control or disease prevention.

Crow acknowledges the strain. The focus on economics, he says, has left some faculty members feeling that earth science and ecology have secondary intellectual status. "That put a tension through the whole organization that has been very difficult to get around," he says. Nor has Eisenberger been as tactful as he might have been, Takahashi adds: "Diplomacy was needed, but was lacking."

Eisenberger responds that some areas of collaboration simply needed more attention than others. "We have to focus on making each of the units successful

COMPONENTS OF COLUMBIA UNIVERSITY'S EARTH INSTITUTE	
Lamont-Doherty Earth Observatory	Founded in 1949, Lamont-Doherty hosts a broad range of earth scientists, including seismologists, paleontologists, petrologists, and glaciologists.
International Research Institute for Seasonal to Interannual Climate Prediction (IRI)	A collaboration between Lamont-Doherty, the Scripps Institution of Oceanography, and the National Oceanic and Atmospheric Administration, IRI will focus on the human impact of climate change.
Biosphere 2	The desert greenhouse will explore how changing carbon dioxide and temperature will affect Earth's ecosystems; it also hosts tourists and students.
Laboratory of Populations	A joint venture with Rockefeller University, the laboratory studies topics ranging from coastal population densities to the spread of Chagas' disease.
Center for Climate Systems Research	A collaboration with the NASA Goddard Institute for Space Studies, the center specializes in computer climate modeling and reconstructing past climate changes.
Program on Information and Resources	The program combines mathematics, economic theory, and data analysis to determine the economic value of ecosystems.
The Center for Environmental Research and Conservation (CERC)	A joint effort with a variety of conservation organizations and museums, CERC studies ways to combat loss of biodiversity.
Earth Engineering Center	The former School of Mines looks for ways to provide raw materials in an Earth-friendly manner and reduce damage from natural hazards.
Earth Policy Studies Program	The program offers graduate degrees and hosts researchers studying topics such as how environmental degradation can trigger wars.
Institute for Biosphere and Society	The institute aims to link science with economics and finance to devise economically beneficial ways to protect the environment.
Consortium for International Earth Science Information (CIESIN)	Columbia persuaded CIESIN, a nonprofit center for earth science and social science data, to move from Michigan to the Lamont-Doherty campus.

in its own right," he says. "If each of these things is amazingly successful, we will have a foundation, and the integration will happen almost naturally." He adds that he's been through similar transitions before, when he set up the Princeton Materials Institute, and before that at Exxon, where he organized a center for the study of complex systems. Efforts to yoke separate disciplines to a common vision always pass through a "valley of death" before they begin to succeed, he says.

But Lamont's passage through the valley may leave some scars. At least one longtime researcher will leave this fall—in part, he says, because of the new direction at Lamont. Broecker has threatened to leave as well, although he now says he will wait through the summer to see if the situation improves. Both Crow and Eisenberger say that Lamont may soon get a separate director. "What we're finding is that the task of running the Earth Institute as a whole and running Lamont is quite difficult," Crow says. Eisenberger says he is open to possible management changes: "It wasn't me who insisted on both jobs."

Even those who are most upset by the changes at Lamont endorse the concept of the Earth Institute, however. "The rationale is good," says the researcher who is leaving this fall. "It does identify what some people say is the key problem of the 21st century. Regardless of where I sit, it's an interesting experiment."

–Gretchen Vogel

HUMAN GENOME PROJECT

Funders Reassure Genome Sequencers

COLD SPRING HARBOR, NEW YORK—J. Craig Venter, president of The Institute for Genomic Research in Rockville, Maryland, dominated an international meeting* of genome researchers here last week, although he wasn't even present. Scarcely a session went by without a reference to Venter's stunning announcement, just 4 days before the meeting began, that he plans to team up with the Perkin-Elmer Corp. of Norwalk, Connecticut, to form a new company to sequence the human genome in 3 years (*Science*, 15 May, p. 994). Because many of the meeting participants are involved in a vast public program to do the same thing by 2005, the subtext of the gathering was: What does Venter's proposal do to our plans?

Virtually everybody here seemed to reach the same conclusion: Because of uncertainties surrounding Venter's approach and fears about data-hoarding by a private venture, the public effort should be stepped up. The strongest response along those lines came from the United Kingdom's Wellcome Trust, one of the world's largest sources of biomedical research funds. On 13 May, it announced that it will double its investment in the international sequencing project. And Francis Collins, the director of the National Human Genome Research Institute (NHGRI), assured meeting participants that the U.S. Human Genome Project (HGP) will continue as planned. "It is critical that we not retreat from our goal," Collins said.

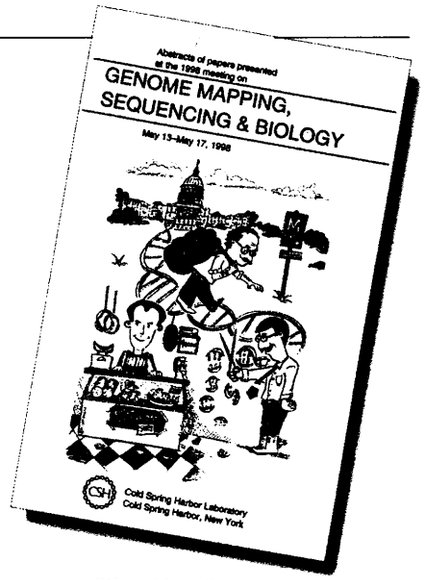
The Wellcome Trust's program director for genetics research, Michael Morgan, said that the trust now plans to put $325 million into completing about one-third of the total human genome sequence by 2005. If necessary, he added, it may be prepared to sequence as much as half the genome. The work will be done at the Sanger Centre near Cambridge, U.K. Morgan emphasized that the increase had been in the works for months, but said at the meeting that the decision to publicize it "was to a certain extent a response to the announcement" by Venter and Perkin-Elmer.

The Wellcome Trust hoped its announcement would allay fears that Venter's plans would jeopardize the international sequencing effort, yet produce a genome that falls short of the original standards for completeness and accuracy. These require that there be no more than one mistake per 10,000 base pairs and, ultimately, no gaps in the sequence data. The new company will take a brute-force approach, sequencing the entire genome at once using a battalion of new machines being developed by Perkin-Elmer. Some researchers have argued that this strategy will leave too many gaps and ambiguities.

Collins cited those concerns last week, noting that "there is a great deal of uncertainty and debate about whether this particular strategy will be able to give us the product desired." He confirmed that NHGRI will go ahead next year with plans to establish a cooperative research network of about a dozen sequencing centers, at a total cost of $90 million. "There will be no backing away from the notion that this is our major effort," he said at the meeting.

Even Venter agrees that "right now, they should keep doing what they are doing until they have had a chance to scientifically evaluate [the new approach]." Although he maintains that his company's sequence will be as accurate and as complete as the publicly funded genome, "it's fair to have that skepticism," he said after the meeting. He said he plans to test the new approach by sequencing the genome of *Drosophila*.

Aside from concerns about quality, reaction to Venter's announcement has been tinged by fears that the new company will stake a proprietary claim on much of the genome. Venter has said that the company will patent only 200 to 300 genes, but others don't want to depend on that promise. As Glen Evans, who runs a sequencing center at the University of Texas Southwestern Medical Center at Dallas, puts it, "we don't want Craig Venter to become the Bill Gates of biology." Morgan says the Wellcome Trust shares that concern: "Our concern is that biotechnology companies may try to Hoover up basic sequence data. ... We will challenge any such patent applications."



Genome politics. More than research was debated at this annual meeting.

For the most part, genome researchers were cheered by both the Wellcome and Collins announcements. "It was good to let everybody know where we are going," says Rick Myers, co-director of Stanford's human genome sequencing center. "It would be horrible if the [HGP] gets derailed." A few worried, however, that NHGRI is not doing enough. Evans, for example, says that sequencers should now focus on producing data faster than Venter can and, for the time being, worry less about accuracy and piecing that data together. He also argues for more funding, pointing out that in the most recent awards, the sequencing centers didn't get what they asked for to scale up their programs. Still, some think the Perkin-Elmer venture will be a boon to their own efforts. The new company "will help galvanize us and [make us] work together," predicts Myers.

–Elizabeth Pennisi

With reporting from Nigel Williams.

* The 1998 Genome Mapping, Sequencing, and Biology Meeting, 13–17 May.