ENVIRONMENTAL SCIENCE

Biocomplexity Blooms in NSF's Research Garden

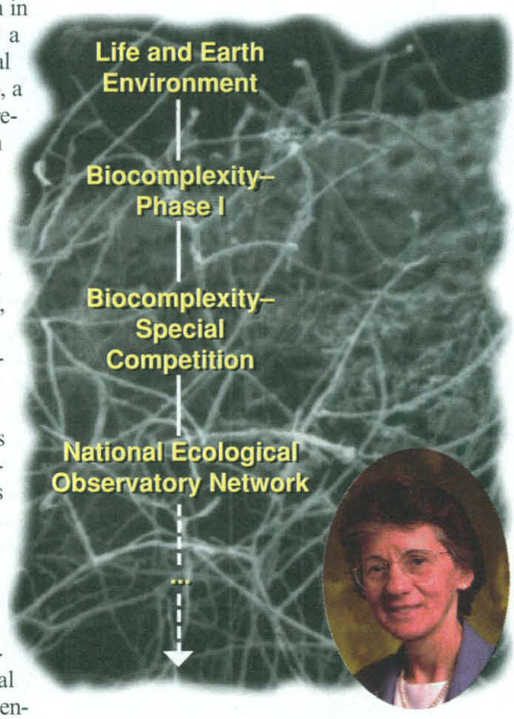
Director Rita Colwell hopes to persuade both politicians and scientists that a hard-to-define term is the hottest research game in town and a key to understanding the world

Biocomplexity. It's been a buzzword for Rita Colwell since she became director of the National Science Foundation (NSF) 16 months ago. Now, the nebulous concept is gradually taking on form and substance as the centerpiece of an expanding environmental research portfolio at the $4 billion agency.

On 3 December NSF spelled out the rules for a $50 million special competition for research on the topic—the second since Colwell took office (NSF 00-22). Its call for interdisciplinary proposals "to better understand and model complexity in biological, physical, and social systems" comes as NSF officials are lobbying hard for $30 million in the president's 2001 budget request as a downpayment on a $100 million National Ecological Observatory Network (NEON), a collection of outposts that would provide researchers with the capacity to do high-tech fieldwork on biocomplexity. Both initiatives are consistent with an upcoming report by NSF's governing body, the National Science Board (*Science*, 6 August, p. 816), that recommends that the agency nearly triple its environmental spending, from $600 million to $1.6 billion a year, over the next 5 years. And more than money is involved. Next month, paleoceanographer Margaret Leinen of the University of Rhode Island (URI) takes over as NSF's first environmental "czar," with responsibility for integrating these new programs into a portfolio of environmental research that ranges from understanding magnetic storms in space to exploring life in deep-sea vents (see sidebar).

"Biocomplexity is a multidisciplinary approach to understanding our world's environment," Colwell told a congressional panel earlier this year. "For generations, scientists have studied parts of our environmental system—individual species and habitats—in isolation. Now it is time for a better understanding of how those parts function together, as a whole."

Even NSF staff involved in some of the biocomplexity initiatives confess that they don't yet have their arms around the concept. "It's still evolving," says one program officer. "It's not at all clear how it will shake out." The concept may not be a whole lot clearer to scientists in fields most likely to benefit from the jump in funding, but they like what they've heard so far. "We think it's great, and we're eager to learn more about it," says Alan Covich, an ecologist at Colorado State University in Fort Collins and president-elect of the 66-society American Institute of Biological Sciences (AIBS), which has already chosen "From Biodiversity to Biocomplexity" as the theme for its 2001 annual meeting. "What's most exciting about biocomplexity," says Covich, who studies the interaction of marine life, vegetation, and land use on a freshwater system in Puerto Rico, "is its emphasis on the importance of scale, from micro to macro, as well as its inclusion of the social and behavioral sciences—economics, anthropology, and geography—into studies of the ecosystem."



Evolving concept. Four components of Rita Colwell's biocomplexity initiative, which seeks to understand complex systems such as the interaction of mycorrhizal fungi, soil, and white oak roots.

Within months of arriving at NSF in August 1998, Colwell had tapped into a discretionary fund to support a competition for research proposals on how microorganisms affect larger biological, chemical, geological, and even social systems. In late September NSF awarded $13.3 million—twice the amount originally planned—to five teams of scientists in what was called biocomplexity, phase I, with two more awards in the pipeline. "We were grinning for weeks," Caroline Bledsoe of the University of California, Davis, recalls after receiving $4.8 million for a 5-year, three-institution effort to study the interactions of mycorrhizal fungi, plants, and soil in the transfer of carbon and nutrients. Other projects include examining how nitrogen fixation in the oceans affects global climate and analyzing how the genetic makeup of symbiotic bacteria affects the plant-feeding insects that act as their hosts.

The overwhelming response to that hastily assembled special competition—NSF got 118 preproposals, and 34 groups were asked to submit a more detailed package—suggested that NSF had struck a chord in looking for ways to meld diverse approaches to studying large and varied ecosystems. "For 30 years we've taken a reductionist approach, and we have collected a lot of data," says Mary Clutter, head of the biology directorate and coordinator for the initiative. "Now we want to synthesize it and come up with models and theories that explain much broader phenomena."

The just-announced second competition, drawing on the $50 million approved in October by Congress for the current 2000 fiscal year, encourages researchers to think in the broadest possible terms. In an attempt to be helpful, the solicitation describes the sorts of problems that researchers might want to attack: Do the physical arrangement of genes in our DNA and neurons in our brains share patterns with the underground network of bacteria, fungi, and plant roots that nourish the planet, and can computers be used to explore such large-scale networks? How do current property laws and age-old cultural norms affect the rate of deforestation in tropical regions? And what is the mechanism by which human activities affect species diversity? "It's not more of the same thing," says Amy Ward, director of the Center for Freshwater Studies at the University of Alabama, Tuscaloosa, and president of the Association of Ecosystem Research Centers. "It's a more organized effort to study complex problems, and it sets the stage for tackling more critical issues down the line." Letters of intent are due 31 January, with full proposals a month later.

NSF has also set aside $5 million for those interested in pursuing such topics but who aren't quite ready to take the plunge. The money would go for small grants to finance workshops, real or virtual, for like-minded scientists who otherwise might not interact. "We want

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NSF's New Czar For Environment

Paleoceanographer Margaret Leinen wears many hats at the University of Rhode Island (URI)—as dean of the graduate school of oceanography, vice provost for marine affairs, and interim dean of the school's college of environmental and life sciences. That broad purview will stand her in good stead when she comes to Washington, D.C., next month to be the National Science Foundation's (NSF's) first environment czar, responsible for coordinating environmental science and engineering programs. Leinen, 53, will also be replacing Robert Corell as head of NSF's $500 million geosciences directorate, one of seven research directorates at the foundation and a major player in many of NSF's environmental activities.

Leinen, who studied sedimentation in the ancient oceans and its relationship to climate change before becoming an administrator, says she relishes the chance to run the geosciences program. But it's the novel role of environmental czar that led her to take leave from URI, where she's spent her entire professional life, and accept an invitation from NSF director Rita Colwell to join the federal government. "Rita is obviously committed to closer collaboration between the social and the natural sciences," says Leinen, and so is she. In fact, Leinen said that a chance to wear the environmental hat helped to seal the deal after she topped NSF's list during an extended search to replace Corell, who has led the directorate since 1987.

Leinen's first challenge will be to define her role in such existing activities as NSF's new biocomplexity initiative (see main text), now run by biology head Mary Clutter, and the U.S. Global Change Research Program, a $1.6-billion-a-year interagency colossus that Corell has chaired since its inception in 1990. It may be hard to avoid stepping on toes, but her colleagues at URI say she should be able to avoid major collisions. "She gets along with everybody, and she's very personable," says John Knauss, a professor emeritus at URI and former dean who has known Leinen since she was a graduate student. "She knows how to hit the right notes in managing people." Adds Ted Moore of the University of Washington, Seattle, a former mentor and colleague, "I think that geosciences at NSF will be in good hands with Margaret at the helm."

On board. Oceanographer Margaret Leinen will also head geosciences.

Although reluctant to spell out her priorities, Leinen says she believes environmental scientists need to play a larger role in educating students and the general public about how science and technology affect their lives. "We especially need to talk to minority communities about the need for them to be more active," she says. "We have not done a good job of informing them about the [environmental] issues they are facing." It's clear that Leinen, like her boss, is ready to think broadly about environmental science and NSF's role in advancing it. **–J.D.M.**

people from different disciplines to address the big questions, but we know not everybody is ready to do that yet," says Clutter.

For those who are, and who need field data, there's NEON. Each of its stations would be equipped with such instruments as gene sequencers and sensor arrays, as well as sufficient computing power to handle petascale databases and to carry out complex simulations. The technological firepower would allow scientists to modify their collection efforts immediately rather than waiting for the next season. Clutter, whose directorate is overseeing the initiative, hopes to hold a competition next year to choose three sites, and to build as many as 10 over 3 years. Each station would cost $10 million to build and equip. "This is a new concept for field biology," says NSF's Scott Collins, who is organizing meetings in January and March for scientists to hash out both the concept and the technological requirements for the chain of observatories. "They would be like telescopes, with a 30-year life-span, and together they would give us the capability to do high-tech, long-term experiments on the scale of up to an entire continent."

The biggest unanswered question for NSF administrators is how the biocomplexity initiative and its relatives, including NEON, fit into existing environmental research programs at the agency. A few years ago, for example, NSF launched a small interdisciplinary program, Life and Earth Environments, that explores the interaction of biological and physical systems. And for the past 20 years NSF has supported a network of Long-Term Ecological Research (LTER) sites that carry out fieldwork in a variety of ecosystems, a component of the new NEON stations. Indeed, LTER sites will be eligible for NEON awards.

The next step for NSF officials is to figure out how to weave everything together in a format that's both intellectually rigorous and politically compelling. "Biocomplexity provides the spark that can lift the entire [environmental] portfolio," says Marge Cavanaugh, a chemist who heads an internal panel looking at how to implement the science board's recommendations. "It's an opportunity to take a conscious look at whole systems, including the necessary technology and human interactions needed to understand them."

That, in large part, will be the job of URI's Leinen. And Colwell's political success to date gives her a head start. For example, NSF's biocomplexity initiative is faring better in Congress than a new and related interagency effort called Integrated Science for Ecosystem Challenges (ISEC), for which the Administration sought $96 million to explore, monitor, and combat such environmental assaults as invasive species, eutrophication, and habitat destruction. NSF received its full $50 million request for biocomplexity, and $8 million for its slice of ISEC, by arguing that its role is to support the basic research that precedes and underlies any response to environmental assaults. In contrast, Congress cut by nearly 80% the proposed budgets for the other five, more mission-oriented agencies—including the geological survey, the agriculture department, and the forest service. "Biocomplexity is an NSF initiative, to fund basic environmental research," Colwell says. And NSF's contribution to ISEC, she adds, is to provide the knowledge that forms a basis for action under ISEC.

In fact, NSF's success in promoting its environmental agenda may make the other agencies a bit jealous. "We're extremely pleased that NSF is faring so well, and that university-based research is being strengthened," says the Interior Department's Mark Schaefer, who oversees ISEC. "But the applied programs need resources, too."

A few days before Colwell was confirmed as NSF director, she told an AIBS audience that humanity's goal for the 21st century ought to be "to understand, and learn to keep in balance, the biocomplexity of all of Earth's ecosystems ... and to tease out from those subtle but sophisticated interactions the principles of sustainability." Since then, she's made it clear that she wants NSF to play an important role in that quest. **–JEFFREY MERVIS**

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