Experiment is a research endeavor that examines the relationship between ENSO and other climate-related phenomena and human health, and explores the potential for using climate forecast information to provide early warning of conditions posing a public health threat. The project is coordinated by the National Oceanic and Atmospheric Administration and was initiated in 1997 as a result of the colloquium. The ENSO Experiment studied the 1997–1998 ENSO then underway; today, studies sponsored by several different agencies continue to track the human health aftermath of that phenomenon.

Second, modeling studies must be undertaken to elucidate links between climate and infectious disease. According to the report, one of the primary goals of model building for research on weather–disease links is to be able to predict outbreaks of disease in response to particular climatic variables. The report says models are needed not only to organize and assess the new data that are being collected, but also to reassess data that are already available. Several new models are being developed, such as a model by Mercedes Pascual of the Center of Marine Biotechnology at the University of Maryland Biotechnology Institute in Baltimore, which will examine the predictability of cholera in endemic regions and its relationship to climate variability.

Third, the report stresses the need for collaboration and communication among scientists, and between scientists and the public. The report calls for an international collaborative research effort and the establishment of new research centers specifically to study the relationship between climate, weather, and disease. The report also cites the need for increased and longer-term funding. Traditional research funding cycles run 2–3 years, which is in sharp contrast to the 25 years recommended by the report for a comprehensive study documenting the weather–disease relationship. The report particularly stresses the need to develop new weather–disease databases, linked nationally and internationally, that are interdisciplinary in content and accessible to all interested researchers, and to link existing databases maintained by independent groups of scientists. The report points out that, while there are electronic data sets to be found all over the world, few of the existing databases are either coordinated or designed to be used in conjunction with others.

Finally, the report calls for the drafting of a shared terminology to unite scientists separated by language and discipline, and for scientific journals to publish weather–disease articles that straddle traditional disciplinary boundaries. The report also urges graduate and medical schools to implement courses in weather–disease studies, and encourages scientists to gain popular support for such research by educating the public through demonstration of the value of this research to society.

The When, Where, and How of Environmental Hazards

When the TV news forecasts sun but clouds loom instead, life goes on. People shrug, curse, and grab an umbrella. But when scientists try to predict global warming, earthquakes, or nuclear waste leaks, their uncertainty is much harder to shake off. Then there's the question of what to do in the face of such uncertainty. At the annual meeting of the American Association for the Advancement of Science, held in Anaheim, California, in January 1999, scientists debated the use and abuse of scientific predictions in environmental policy, as well as the traditional policy of erring on the side of caution when in doubt as to the nature and extent of environmental hazards.

In one session, scientists took turns revealing gaping holes in scientific prediction. For instance, Orrin Pilkey, a geologist at Duke University in Durham, North Carolina, and Daniel Metlay of the U.S. Nuclear Waste Technical Review Board lamented the decade-old dispute over storing radioactive waste under Nevada's Yucca Mountain. Under pressure to pick a spot for dumpling the waste, Department of Energy policy makers put blind faith in mathematical models of pollution flux at the site, said Pilkey. Relying on these models for years, scientists didn't bother to draw water samples from under the mountain, he said, and when they did, they found it hard to predict whether the waste might in fact seep into groundwater. Following the discovery, political debates, scientific wrangling, and media headlines ensued. By then, Metlay added, the department's policy makers had become "hostages of time," struggling to meet federal waste disposal deadlines and relying on mathematical models to help do it.

There's a smarter route to environmental prediction, Pilkey and Metlay said—a tighter partnership between policy makers and scientists, complete with plenty of independent geology research for any proposed nuclear waste site, and less reliance on models. This call for better communication between scientists and policy makers resounded at the session, as the panel outlined uncertainties in global climate change, California earthquakes, and eroding North Carolina beaches. Better communication, said Daniel Sarewitz, a geologist at Columbia University in New York, "allows the policy makers to understand the limits of science, and it allows scientists to understand what policy makers need to know."

Such communication is not the current paradigm, said Sarewitz, who has worked as a consultant to the House of Representatives Committee on Science, Space, and Technology. He said that climate
change is one example of the United States’ flawed approach toward weaving scientific prediction into policy. “The idea is that a scientific answer—[for instance,] a global warming prediction—can be found, and then policy makers can apply rules to deal with it.” A better tactic, Sarewitz said, is to recognize up front that scientists may never know enough to predict global warming accurately. They might do more good teaming up with policy makers and everyday citizens to find alternatives to prediction such as flexible strategies that may help a given community confront the range of global warming possibilities. “The instinct is to predict,” Sarewitz said. “But the promise of prediction just isn’t always met.”

In such cases, age-old adages such as “better safe than sorry,” “first, do no harm,” and “look before you leap” may come into play. The transformation of such adages, however, into an emerging environmental philosophy caused great debate at the meeting. Scientists explained the theory behind and possible uses of the so-called “precautionary principle,” which holds that industry and governments should prevent pollution, technology, or other activities that have even the potential to harm human or environmental health.

The controversy lies in the fact that some scientists suggest society should go as far as stopping a new technology or polluting activity in its tracks when it appears that it might harm others—even if scientists can’t actually prove that it does. While this idea has crept into a few pollution laws in Germany and the United Kingdom, it’s a far cry from environmental policy in the United States, which relies on techniques such as risk assessment and cost–benefit analysis to weigh the pros and cons of a polluting activity. Toxicologists at the meeting pressed the scientific panel to explain how they could base sound environmental policy on a philosophy that doesn’t require scientific certainty about a substance’s toxicity. Steve Breymann, a political scientist at Rensselaer Polytechnic Institute in Troy, New York, countered that he and others want to “err on the side of human health,” and that there are many examples, such as lead poisoning and smoking, of how people’s health suffered while scientists debated risk.

Ken Geiser, director of the Toxics Use Reduction Institute at the University of Massachusetts in Lowell, described several relatively easy ways to put the precautionary principle into play, such as replacing potentially toxic chemicals with more neutral substitutes, recycling materials, and tinkering with production processes to produce less pollution. For the past decade, the institute has been advising Massachusetts companies how to do these things without hurting profits or productivity. Geiser and his colleagues advocate “clean production,” a style of manufacturing that cuts pollution to minimal levels. This kind of approach, Geiser argued, is a feasible way to a more sustainable society.

The primary push for the precautionary principle comes from the Science and Environmental Health Network, a national nonprofit organization of scientists and environmentalists. It remains to be seen whether the U.S. Environmental Protection Agency or other federal government agencies will ever formally adopt the principle, Breymann said. He suggested, however, that increasing disease and ecosystem damage may bring precaution foremost in the public’s mind.

**Tracking Risk**

When the cluster of children’s leukemia cases featured in the recent movie *A Civil Action* surfaced in Woburn, Massachusetts, in the mid-1980s, state epidemiologists weren’t even tracking cancer cases. Scientific scrutiny of the interplay between genes and the environment has come a long way since then. But panelists at the annual meeting of the American Association for the Advancement of Science, held in Anaheim, California, in January 1999, posed the question that now presents itself to researchers crossing traditional disciplinary boundaries: how to decipher ever-larger amounts of complex data.

“We’ve gone about as far as we can go independently with the two sciences that feed public health, toxicology and epidemiology,” said panelist Christopher Schenwalder, the NIEHS director of international programs. “Now is the time to bring them together if our understanding is to advance,” he said.

Combining cancer registries and right-to-know laws, for example, boosts the study of environmental hazards, said Sandra Steinrager, an ecologist with the Women’s Community Cancer Project and author of *Living Downstream*. “Thanks to activism, a pipeline is being built between the two giant databases,” she said.

Investigators have recognized the futility of tracking the risk from specific etiologic agents, pointed out Devra Lee Davis of the World Resources Institute, “because disease patterns will always reflect mixed environmental hazards.” Similarly, exposure patterns are used more to provide warnings about potential hazards than to forecast disease outcomes. “Exposure occurs to a finite number of materials,” Davis said. “Health is a function of many variables.”

Studying genes or the environment independently, panelists said, is giving way to studying the interactions that cause human disease. Yet, according to Columbia University researcher Ruth Ottman, “There has been surprisingly little work to date on what that interaction is, how to detect it, and what kinds of study designs should be used to look at these questions.”

Modelers face challenges on both fronts. Efforts to develop models to describe the risk of exposure from single agents have been frustrated, reported Oak Ridge National Laboratory researcher Troyce Jones. The carcinogenic mechanisms are simply too complex, and the immune system too variable. “In spite of all the knowledge at this meeting and all the knowledge in the published literature, we can barely, barely get past ‘go’ going either direction—backwards from disease to exposure, or from exposure to disease,” Jones said. As researchers continue to shift from answering the question of what a dose is to what a dose does, he said, better risk assessment and policy can be formulated. Specifically, he said, analysis of databases derived from considerations of reactive oxygen can generate direct indices of how the immune system is modulated by different environmental variables.

Joellen Lewtas, a toxicological chemist with the U.S. Environmental Protection Agency, reported success with using biomarkers in her work in the Czech Republic to look at the progression from exposure to what ultimately could be increased cancer risk. DNA adduct measurements from the study, in particular, offer some opportunity to combine epidemiological data with toxicological data, Lewtas explained. Such measurements reflect not only exposure, absorption, and transport but also metabolism, DNA repair, and cell turnover. “Biomarkers can provide very specific evidence of exposure and confounding exposures,” Lewtas explained. “They can be used to evaluate molecular dose and damage related either to health outcomes or . . . to the exposure biomarkers, which in turn provide the basis for studying susceptible subpopulations.”

Researchers attempting to interpret data on disease susceptibility genes face equally complex problems. “For the most part, we have a hard time explaining the effect of one gene polymorphism in relationship to an exposure,” said NIEHS researcher Douglas Bell.

Although researchers working with the Environmental Genome Project and similar projects have identified roughly 60,000 variants among disease susceptibility genes