Conference on Human Health and Global Climate Change

Summary of the Proceedings

National Science and Technology Council
and the
Institute of Medicine/National Academy of Sciences

Written by Paul B Phelps for the Institute of Medicine

Valerie Setlow and Andrew Pope, *Editors*

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NOTICE The conference that is the subject of this summary was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine

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This summary was prepared by Paul Phelps for the Institute of Medicine It summarizes the presentations and discussions that occurred during a 2-day conference (September 11–12, 1995) that was organized and conducted in a collaborative effort between the Institute of Medicine, the National Academy of Sciences, and the National Science and Technology Council (NSTC), with support from several member agencies of the NSTC The views summarized in this report are those of the conference participants and do not represent the views of the NSTC or the Institute of Medicine and National Academy of Sciences This summary was reviewed for accuracy by the chairs of the individual sessions of the conference and by the chairs of the breakout group panels

Funding for the conference was provided by the National Academy of Sciences, the Office of Science and Technology Policy, the National Science Foundation, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the Department of Defense, the National Institutes of Health's Fogarty International Center and the National Institute of Environmental Health Sciences, the Department of Agriculture, the Centers for Disease Control and Prevention, the Agency for International Development, and the Department of Energy

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The serpent has been a symbol of long life, healing, and knowledge among almost all cultures and religions since the beginning of recorded history The image adopted as a logotype by the Institute of Medicine is based on a relief carving from ancient Greece, now held by the Staatlichemusseen in Berlin

Acknowledgments

The Conference on Human Health and Global Climate Change that is the subject of this summary was the product of a collaborative effort between the Institute of Medicine, the National Science and Technology Council (NSTC), and the National Research Council's Board on Atmospheric Sciences and Climate, Board on Sustainable Development, and Polar Research Board It would not have been possible without the concerted efforts and contributions of many individuals and organizations The conference planners and organizers are listed in Appendix B, including the NSTC Working Group, the sponsoring agencies, the IOM/NAS Steering Committee, and the responsible staff The conference speakers, background paper authors, and session chairs deserve special recognition and thanks for their efforts and are listed in Appendix C The approximately 300 conference participants were an important part of this activity, especially in stimulating discussion, providing ideas, and developing the strategies that were the products of the individual working group panels These individuals are included in the list of conference registrants in Appendix C

Of particular note, Eric Chivian, Bob Shope, and Mary Wilson are acknowledged for their contribution in both raising and discussing these issues with Vice President Albert Gore, Jr , in the formative stages of the conference's development and for their participation in the conference itself We also would like to acknowledge Vice President Gore for his initiative in requesting that this conference take place, and for his contribution as a participant and speaker

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Conference on Human Health and Global Climate Change: Summary of the Proceedings

EXECUTIVE SUMMARY

Observed changes in the Earth's climate over the past 100 years appear to be consistent with theoretical models of greenhouse warming, according to the participants in a recent scientific conference on Human Health and Global Climate Change, cosponsored by the National Science and Technology Council (NSTC) and the Institute of Medicine (IOM)[1] These models suggest that, without major changes in environmental policy, we could expect to see even greater changes in global climate over the next 100 years These changes could produce alterations both in physical systems (e g , higher temperatures, heavier rainfall, and rising sea level) and in ecosystems (e g , forests, agriculture, marine ecologies, and the habitats of various insects and animals) In addition to the global changes associated with greenhouse warming, a continuing depletion of stratospheric ozone would increase the amount of ultraviolet radiation that reaches the Earth's surface, causing increased rates of skin cancer, cataracts, and immune suppression

The focus of concern to the conference participants was the substantial risks to human health, including both direct risks (e g , death in heat waves or floods, skin cancer) and indirect risks (e g , changes in food production or the distribution and incidence of vector-borne diseases) that are believed to be associated with changes in global climate The indirect risks appear to be the most difficult to cope with, particularly those posed by emerging and reemerging infectious diseases such as cholera, malaria, dengue fever, and Hantavirus These risks are of particular concern in regions and populations that are already vulnerable due to crowding, malnutrition, poor sanitation, and political or economic instability

The general agreement that emerged during the conference was that changes in the global climate could pose significant risks to human health Much remains to be done to clarify the exact linkages between human activities, global climate change, and human health, but the lack of complete data should not be used as an excuse for inaction Instead, the precautionary principle should apply If the risk to public health is great, even if there is uncertainty, both policy and action should be biased in favor of precaution

In discussing the policy implications of global climate change for human health in the United States and the international community, participants identified a number of actions that should be taken, including (a) the creation of a global surveillance and response network, (b) increased

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[1]The conference was held at the National Academy of Sciences on September 11–12, 1995, and was attended by more than 300 people (see Appendix C)

coordination among nations and scientific disciplines, (c) multidisciplinary research on the links between global climate change and human health, (d) improved environmental health training for health professionals, and (e) an outreach program to inform and educate the public about the effects of global climate change on human health In the face of current fiscal constraints, these efforts must be based on identifying and linking together existing activities, facilities, organizations, and funding agencies

BACKGROUND AND OVERVIEW

In October 1994, following a meeting with concerned scientists and medical experts (Eric Chivian, Bob Shope, and Mary Wilson), Vice President Gore asked the Office of Science and Technology Policy (OSTP) and the Council on Environmental Quality (CEQ) to organize a conference on the potential human health risks posed by global climate change, and strategies to address them—such as global health surveillance, public outreach, and education Members of the NSTC, OSTP and CEQ formed a working group to develop a preliminary agenda for the conference and later requested that the IOM join in planning, organizing, and conducting the conference (Appendix A presents a list of the sponsoring agencies, the IOM steering committee, and conference organizing staff)

The purpose of the conference was twofold

1 To bring together a diverse, interdisciplinary group of experts to address the potential effects of global climate change and ozone depletion on the current and future incidence of disease, heat stress, food and water supplies, and air pollution, and

2 To discuss initial strategies for improving research and development (R&D), global health surveillance systems, health care and disease prevention, medical and public health community education, international cooperation, and public outreach

It is important to note that the focus of the conference was human health Presenting evidence of whether or not global climate change is, has, or will occur, was not the primary focus Participants were asked rather to work within an "if/then" type of scientific exercise If global climate change occurs, what are the potential adverse human health effects and what strategies should be developed to address them?

The first day of the two-day conference was filled with scientific presentations and a plenary discussion on the current state of knowledge about global climate change and its potential risks for human health (see the agenda, Appendix B), including a presentation by Vice President Gore (see Box 1) On the second day, participants discussed health policy implications and potential intervention strategies in a series of panels Each panel's findings were presented and discussed by the conference participants in a final plenary session Approximately 300 scientists, health care providers, policymakers, academicians, federal and state officials, industry representatives, and others attended the conference and participated in developing the strategies (see Appendix C)

BOX 1 The Interplay of Climate Change, Ozone Depletion, and Human Health

Albert Gore, Jr
Vice President of the United States

I've spoken before about the radical changes that have occurred in our environment just in my lifetime As is often the case, when a fundamental change takes place, one can't point to a single causal factor to explain it In this case, I've come to believe that this radical change in the relationship between civilization and the Earth has come about because of the confluence of three factors at the same time, the first being the population explosion, which is now adding the equivalent of one China's worth of people every 10 years The second change is the scientific and technological revolution, which has dramatically magnified the average impact that each of the billions of people on Earth can potentially have on the Earth's environment And the third factor, the most subtle in some ways but the most important in other ways, there has been a change in thinking about our duty to consider the future consequences of our present actions and a sometimes willful assertion that we can't possibly have any meaningful impact on the Earth's environment, therefore we shouldn't think about it much less worry about it or study it in detail Together, these three elements have combined to produce what some of you would call a discontinuity a fundamental change in the relationship between human civilization and the earth

There is a scientific consensus on the most salient issues, a revisionist few not withstanding We know that human activities are causing the atmospheric concentrations of greenhouse gases to increase dramatically in the atmosphere Carbon dioxide has increased nearly 30 percent since the industrial revolution, methane has more than doubled, and nitrous oxide has gone up by 15 percent We also know that the current trends are leading to an even more rapid accumulation of greenhouse gases and that, as this trend continues, the concentration of greenhouse gases will continue to mount Now, in addition to the greenhouse gases, human activities have increased the atmospheric concentrations of sulfate aerosols—the key ingredient in acid rain—especially over industrialized areas in the Northern Hemisphere

In just the last century, the Earth's temperature has risen by about 0 5°C, or 1°F The nine warmest years this century have all occurred since 1980 There are plenty of other measures—from the tree-ring record to the record in land-based glaciers—that all demonstrate that the current period is by far the hottest that we have been able to measure And the evidence is getting ever stronger that this warming now under way is not due to natural variability, but to human activities

The real question is "What will happen in the future?" Without climate change policies that limit global emissions of greenhouse gases, there is no doubt that the Earth's climate will change It's not a question of will it change, it is a question of when, by how much, and where The question of when is now being answered It has already begun to change significantly And the best evidence is consistent with a prediction that in the lifetimes of people now living we will commit the world to an increase of up to 3° and 4°C—up to 8°F The scientists warn us that change is coming

Continued

Excerpts from remarks at the Conference on Human Health and Global Climate Change September 11, 1995

How will global warming affect us? There are clearly profound implications at the regional level for food security, water supplies, natural ecosystems, loss of land due to sea level rise, and human health A temperature increase of 2° to 8°F is projected to double heat-related deaths in New York City and triple the number of deaths in Chicago, Los Angeles, and Montreal And an increase of 8°F may be correlated with an increase in the heat/humidity index of 12° to 15°F The very young, the elderly, and the poor will be the ones most at risk So will those with chronic cardiovascular and respiratory diseases The past summer's stunning number of deaths in Chicago—over 500 in just a few days—make these hypotheses all too real

Changing temperatures and rainfall patterns are predicted to also increase the spread of infectious diseases Insects that carry disease organisms may now move to areas that were once too cold for them to survive These new breeding sites and higher temperatures may also speed reproduction Diseases we had hoped were just a memory in this country are suddenly a renewed threat Cholera is resurgent in our hemisphere After years of being contained in much of the world, Dengue Fever has returned to countries that had not seen the disease in 50 years Malaria, too, is a global concern, and some of the new strains are more troubling than any that have been seen Malaria already infects several hundred million people each year—mainly in the Tropics But this July, for the first time in 40 years, more than 100 people contracted malaria in a Russian city And besides the return of old diseases, there are new ones on the U S scene, such as the hantavirus in the Southwest

Unfortunately, ignoring the news does not make it better Closing your eyes to a problem doesn't make it vanish You can't simply wish ozone holes away So it astounds me, in light of all the data that has been collected over the years, that some are once again challenging the fact that there is ozone depletion And what's even more amazing is that some people are listening Ladies and gentlemen, we have an extraordinary international consensus We have thousands and thousands of atmospheric measurements linking manmade CFCs to global ozone depletion

We all know that depletion of the ozone layer increases the amount of UV-B radiation that reaches the Earth And so now we have to confront the fact that the observed depletion of ozone of 5–10 percent in summertime, when people are outdoors a lot, will increase nonmelanoma skin cancer in fair-skinned populations by about 10–20 percent

In addition, there will be an increase in the incidence of cataracts and other eye lesions, and cataracts are already the third-largest cause of preventable blindness in the United States These numbers would be much higher yet were it not for the success of the Montreal Protocol We must not forget though, that even with that world-wide action, it will be until the middle of the next century before the ozone layer recovers

Well, for the past 25 years, the United States has been committed to the bipartisan effort to protect the environment President Clinton has fought to make sure that the United States is at the forefront of a global environmental movement We're striving to return greenhouse gas emissions to 1990 levels by the year 2000 We're striving to convince others to make as much progress as is possible We're engaged in international negotiations to address this global problem We're helping to develop treaties not only for the protection of our own nation, but for the health and welfare of the world community of which we are a part We know that science is essential to our understanding of global problems

Ladies and gentlemen, the role of the scientific community in articulating clearly the best accepted understanding of what we know and what we can say with sufficient confidence to enable the American people to take prudent measures to safeguard our future is absolutely critical

Greenhouse Warming

Without the naturally occurring "greenhouse effect," Earth would be too cold to sustain life as we know it The greenhouse effect results from water vapor, carbon dioxide, and other trace gases in the atmosphere that trap solar heat as it is reradiated from the Earth's surface The net effect is to keep the planet about 33°C (60°F) warmer than it would be otherwise In the past century, however, human activities have added substantially to this effect by releasing additional greenhouse gases into the atmosphere, primarily through combustion of fossil fuels Carbon dioxide concentrations have increased nearly 30 percent, nitrous oxide about 15 percent, and methane approximately 100 percent The principal source of the emissions that produce the atmospheric concentrations has been the burning of fossil fuels (coal, oil, and gas), although agriculture and deforestation contribute a share

There is a growing consensus in the scientific community that the increase in greenhouse gases has contributed to a warming of the earth's surface by between 0 3° and 0 6°C (0 5° and 1 1°F), on average, over the past 100 years (see Figure 1) In some regions, particularly in the industrialized areas of the Northern Hemisphere, this warming has been masked by increased concentrations of air pollutants such as sulfate aerosols, which reflect solar radiation (and thus serve to counter-balance, in part, the warming that might be seen otherwise) Nevertheless, the nine warmest years in this century have occurred since 1980, and there is considerable evidence to support this warming trend (see "References and Further Reading," p 28) decreases in Northern Hemisphere snow cover and Arctic sea ice, the retreat of glaciers in all of the world's mountain ranges, and a measurable rise in average sea level—10 to 25 centimeters (4 to 10 inches) over the past 100 years—mainly due to thermal expansion of water

While emissions of greenhouse gases will certainly continue in the future, the exact amounts will depend on population growth, economic development, energy technologies, and policy variables Nevertheless, according to the participants, it seems reasonable to expect that global emissions of carbon dioxide will rise in the short term from the current level of approximately 6 billion tons of carbon per year, to between 8 billion and 15 billion tons per year in 2025, and could range from 5 billion to 36 billion tons per year by 2100 This would mean that atmospheric concentrations of carbon dioxide—which were 200 parts per million (ppm) during the last ice age and about 280 ppm in preindustrial times—could rise from today's 350 ppm to anywhere from 500 to 900 ppm by 2100

The scientific community has growing confidence in the ability of computerized general circulation models to predict the climate impacts of such changes in greenhouse gases These models, which provide an increasingly good fit between theory and observation of past global climate changes, indicate that, in a world with approximately twice the current concentration of carbon dioxide, the global mean temperature will increase by 1° to 4°C (2° to 7°F), with significant regional variations (e g , somewhat less warming in the Northern Hemisphere due to air pollution) Average evaporation will also increase, and hence average precipitation, again with regional variations (more rain in some places, especially in winter, less rain in others, especially in summer) Sea level will rise by another 15 to 90 centimeters (6 to 35 inches) over the next 100 years

Participants noted that the impact of such changes on natural and human systems will be mixed Increased carbon dioxide concentrations would have a "fertilizer" effect for some plants, but not for others, leading to changes in natural plant communities and ripple effects on animal species Overall, the balance would probably be tilted in favor of "weedy" species—those with higher rates of reproduction and dispersal—to the detriment of biological diversity Tropical forest communities will be affected, and there will probably be some die-off in boreal forests as well Temperature-related changes in the oceans will affect the world's coral reefs and ocean fisheries Global agricultural production may be unchanged, although increased production in northern latitudes might be offset by decreases in tropical regions where many populations are already malnourished Coastal populations may be dislocated by changes in sea level, and there will likely be increased numbers of other "ecological refugees" as well

Ozone Depletion

A thin layer of ozone high in the atmosphere (the stratosphere) protects life on earth, shielding the surface by absorbing much of the ultraviolet radiation from the sun However, surface ozone (in the lower atmosphere or troposhpere) is a major component of urban smog and can also serve as a

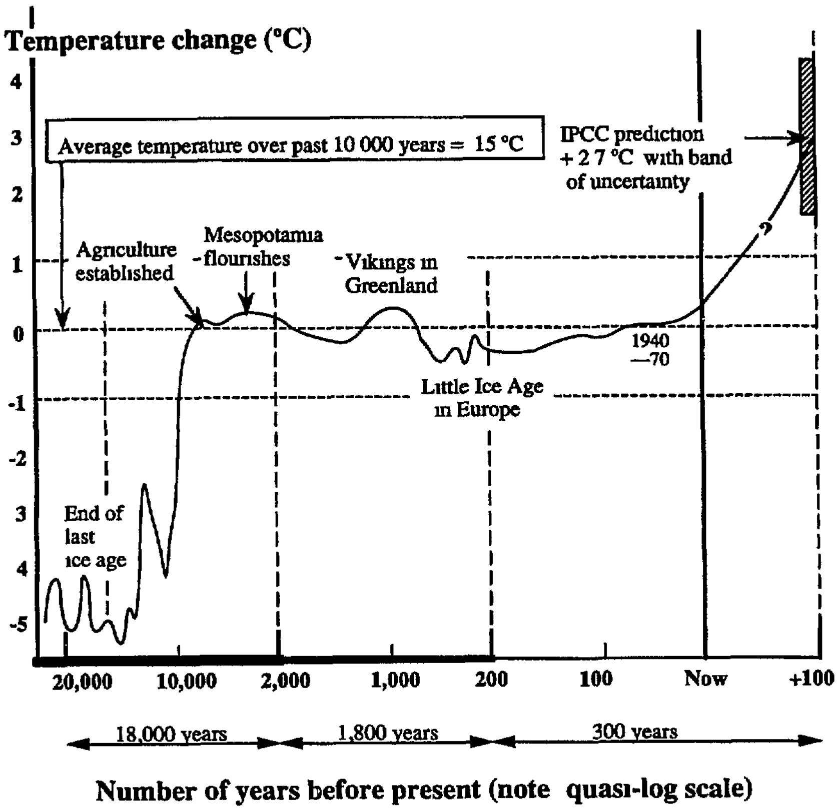

FIGURE 1 Variations in average global temperature over the past 20,000 years and predictions for the next century (McMichael, 1993)

greenhouse gas, the protective ozone layer resides some 10 to 40 kilometers, or 6 to 25 miles, above the Earth's surface Solar energy recombines diatomic oxygen (O_2) into triatomic ozone (O_3), these molecules are broken down to O_2 by naturally occurring compounds containing nitrogen, hydrogen, and chlorine, and the cycle begins again In the past 50 years human activities have added millions of tons of ozone-depleting chemicals to the atmosphere, primarily through the widespread use of chlorofluorocarbons (CFCs) in refrigerators, spray cans, foam insulation, and cleaning compounds

In theory, these ozone-depleting chemicals rise up in the atmosphere and destroy the ozone layer faster than it is naturally restored Indeed, in 1985, researchers reported dramatic declines in ozone concentrations over Antarctica during the southern spring This seasonal "hole" in the ozone shield has grown larger and appeared earlier in subsequent years Many other factors might contribute to these findings, including sunspot cycles and the isolation and extreme cold of the Antarctic weather system, but CFCs and other ozone-depleting compounds were clearly implicated [2]

More recent measurements have confirmed that ozone depletion is in fact a global phenomenon, although it is less acute in the tropics and more pronounced toward the poles, particularly in the Southern Hemisphere At present there is a 5 to 7 percent ozone depletion over the United States during the summer, when people are most likely to be outdoors, about 11 percent over southern temperate areas, and more than 50 percent over Antarctica Every 1 percent decrease in ozone can lead to a 2 percent increase in nonmelanoma skin cancer This phenomenon is expected to continue for the next decades, despite international efforts to ban CFCs and to phase out other ozone-destroying compounds Peak ozone depletion will occur around the turn of the century, recovery is expected to occur over the following 50-year period

POTENTIAL HUMAN HEALTH EFFECTS OF GLOBAL CLIMATE CHANGE

Conference participants noted that the anticipated human health risks caused by global climate change will not be localized, instead, they will occur on a large scale, impinging on entire populations In addition to increasing the familiar, direct effects of climate (i e , extreme weather events such as heatwaves and floods), global change will also involve a variety of indirect risks arising from the disturbance of natural systems (e g , the ecology of infectious diseases, food production, and fresh water supplies) Forecasting these risks is a complex, uncertain task, and encompasses a long time horizon (Box 2 summarizes a pair of presentations on El Niño as an analogue for long-term global climate change)

The health effects of global climate change span a continuum from direct to indirect, as shown in Figure 3 In the long run, the indirect effects of disturbing natural systems may have greater cumulative impacts on human health, and most of those impacts will be adverse As summarized in the most recent assessment of the United Nations Intergovernmental Panel on Climate Change (IPCC, 1995) and by various speakers during the first day of the conference, the most likely and most serious health risks and health effects of global climate change and ozone depletion would be adverse changes in the following

[2]The 1995 Nobel Prize for Chemistry was awarded to Molina and Rowland for this research

- heat stress,
- skin cancer, cataracts, and immune suppression,
- vector-borne infectious diseases,
- non-vector-borne infectious diseases,
- food production and nutritional health,
- water quality and quantity,
- air pollution and allergens,
- weather disasters and rising sea level, and
- social and demographic dislocations

Infectious Disease

Climate influences the distribution, frequency, types, and severity of infectious diseases in humans The interaction between climate and infectious diseases derives from the impact of climate on infectious organisms (such as bacteria and viruses), on the human host, and on vectors and reservoir hosts and their ecosystems Climate change can increase the probability of contact between humans and infectious organisms

Vector-Borne Infectious Diseases

Temperature and rainfall influence the abundance and distribution of insect vectors and animals—one source of infectious diseases in humans Global climate change is likely to affect the geographic distribution of animals and insects and could expand transmission of infectious diseases carried by mosquitoes (e g , malaria, dengue, and yellow fever) and other vectors, such as ticks, sandflies, and fleas Altered distributions of vectors are likely to involve expansion of vector-borne diseases into new geographic areas and populations and disappearance from other areas For a vector-borne disease to persist in an area, climatic conditions must support a complex interaction that may involve plants, animals, insects and human activities

Extreme events, such as flooding and hurricanes, that lead to displacement of populations into crowded, temporary shelters, or movement into previously uncleared lands, could also contribute to an increase in vector-borne infections

Vector-borne diseases are already a major cause of illness and death in tropical countries, where 2 4 billion people are at risk from malaria and 1 8 billion from dengue fever (see Table 1) The numbers of people at risk from these and other diseases will increase with warmer temperatures and humidity, particularly because these changes are occurring simultaneously with changes in human behavior that increase the dangers of infectious disease—most notably international travel, population growth, rapid urbanization, poor sanitation, and changes in land-use patterns that increase habitat or bring humans in contact with insect or rodent vectors Climate-related migrations could also contribute to the dissemination of previously localized diseases Several vector-borne diseases have been increasing rapidly in recent years, including some that were previously considered to be under control, such as dengue fever and malaria Strong support for public health programs both domestically and internationally would help to reduce this risk

Non-Vector-Borne Infectious Diseases

Changes in water temperature and the resulting proliferation of aquatic microorganisms would tend to increase the range and severity of cholera and other food- and water-related diseases that can cause epidemics of diarrhea and dysentery Cholera epidemics are typically associated with seacoasts and rivers, for instance, where the cholera organism, *Vibrio cholerae,* survives by sheltering under the mucous coating of tiny invertebrates called copepods These hosts, in turn, respond both to water temperature and to nutrients (fertilizer, wastewater) in stream runoff Researchers are currently evaluating the connection between water temperature, coastal currents, algal blooms, and subsequent outbreaks of cholera like those in Peru in 1991 and Bangladesh in 1992

Higher temperatures contribute to faster reproduction by disease organisms Rates of genetic mutation also increase in times of stress Furthermore, disease-causing organisms are remarkably resilient and can respond rapidly to changes in the physicochemical environment Climatic and other environmental changes are contributing to the selection and emergence of genetic strains that are resistant to drugs and other controls

Direct Effects on Human Health

Heat Stress

An increase in average temperature would probably be accompanied by an increase in the number and severity of extreme heatwaves in some areas This would cause an increase in illness and death, particularly among the young, the elderly, the frail, and the ill, especially in large urban areas Climate change would exacerbate an already large urban heat island effect that exists in many large cities In fact, heat-related mortality may prove to be the largest direct health threat from global climate change The deaths of 726 people that were attributed to a heatwave in Chicago in the summer of 1995 may be an extreme example, but it serves as a possible indicator of what might occur if climate change scenarios are correct

Mid-latitude cities that experience irregular, but intense, heatwaves appear to be most susceptible—cities like St Louis, Washington, D C , and New York Tropical and subtropical cities seem to be less susceptible, in part because populations have acclimatized to the regularity of hot weather (although a 1995 incident in New Dehli indicates the susceptibility of tropical populations as well) People in mid-latitude cities might also acclimatize, and air conditioning can mitigate perhaps 25 percent of heat-related mortality (while also requiring increased energy and refrigerant use, thereby increasing greenhouse gas emissions) In addition, summer mortality increases might be partially offset by declines in winter mortality However, much of the research points to a substantial increase in weather-related mortality under climate change conditions Despite these uncertainties, there is a clear need to develop an adequate warning system to alert the public and government agencies when oppressive air masses are expected—extended periods of extreme high temperature, light winds, high humidity, and intense solar radiation

TABLE 1 Major Tropical Vector-Borne Diseases and the Likelihood of Change of Their Distribution with Climate Change

Disease	Vector	Population at Risk (million)	No of People Currently Infected or New Cases per Year	Present Distribution	Likelihood of Altered Distribution with Climate Change
Malaria	Mosquito	2,400[b]	300–500 million	Tropics/Subtropics	+++
Schistosomiasis	Water Snail	600	200 million	Tropics/Subtropics	++
Lymphatic Filariasis	Mosquito	1,094	117 million	Tropics/Subtropics	+
African Trypanosomiasis (Sleeping Sickness)	Tsetse Fly	55[d]	250 000–300,000 cases/yr	Tropical Africa	+
Dracunculiasis (Guinea Worm)	Crustacean (Copepod)	100	100 000/yr	South Asia/Arabian Peninsula/Central-West Africa	?
Leishmaniasis	Phlebotomine Sand Fly	350	12 million infected, 500,000 new cases/yr[f]	Asia/Southern Europe/Africa/ Americas	+
Onchocerciasis (River Blindness)	Black Fly	123	17 5 million	Africa/Latin America	++
American Trypanosomiasis Bug (Chagas'disease)	Triatomine	100[g]	18 million	Central and South America	+
Dengue	Mosquito	1,800	10–30 million/yr	All Tropical Countries	++
Yellow Fever	Mosquito	450	<5,000 cases/yr	Tropical South America and Africa	++

NOTE + = likely, ++ = very likely, +++ = highly likely, and ? = unknown

Top three entries are population-prorated projections, based on 1989 estimates [b] WHO, 1995 Michael and Bundy, 1995 [d] WHO, 1994a. Ranque, personal communication [f] Annual incidence of visceral leishmaniasis, annual incidence of cutaneous leishmaniasis is 1 million–1 5 million cases/yr (PAHO, 1994) [g] WHO, 1995

SOURCE IPCC, 1995

BOX 2 El Niño Analogue for Long-Term Global Climate Change?[*]

J Michael Hall
Director, Office of Global Programs, National Oceanic and Atmospheric Administration
and
Paul Epstein
Harvard Medical School

The El Niño southern oscillation (ENSO) may represent an analogue not only for larger-scale global climate change and its consequences, but also for the steps that might be taken to monitor and respond to global climate changes that threaten human health Prevailing winds in the tropics create a pool of warm water in the western Pacific Ocean, a region that drives much of the atmospheric heating that controls the world's weather Periodically, however, the trade winds relax or even reverse themselves, releasing this pool of warm water and setting in motion changes in water temperature, sea level, and coastal currents off South America that—because they happen around Christmas—are known by the name of "El Niño " This oscillation in atmospheric and ocean conditions, which normally happens every 3 to 7 years, causes not only the collapse of ocean fisheries in the eastern Pacific, but also characteristic changes in the weather in other regions, including drought in northeastern Brazil and increased precipitation in the southeastern United States (see Figure 2)

The international scientific community has linked a huge network of ocean buoys and remote-sensing satellites to observe and study the dynamics of the ENSO phenomenon Interdisciplinary research and analysis have led to the creation of multisector models that can predict the occurrence and effects of these changes The ENSO forecasts made by these models are already reliable enough to support major policy decisions In both Peru and Brazil, for example, governments are making decisions about which crops to plant, and how many acres to cultivate, based on 12-month forecasts of ENSO-related rainfall More research and refinement will be needed before these predictive models will be useful in regions outside the tropics and in sectors other than agriculture, including public health Nevertheless, this predictive approach to short-term ENSO changes may have major relevance to the study of long-term changes in the global climate

ENSO-related algal blooms off Peru, for instance, are part of what appears to be a global epidemic of algal blooms caused in part by warmer oceans everywhere These blooms represent "environmental reservoirs" for microbes, such as *Vibrio cholerae*, the cause of cholera in humans Similarly, insect and rodent populations also have increased following the mild wet winters associated with El Niño, and this can have serious impacts in areas where these animals act as pests in agriculture or as vectors for diseases such as malaria and Lyme disease Consequently, the ability to understand and anticipate the relations between global climate changes, environmental responses, and threats to human health may have significant value in developing early warning systems to protect vulnerable populations Multidisciplinary, multisectoral research to develop reliable indicators could have extremely broad benefits for public health

[*]Excerpts from a special briefing at the Conference on Human Health and Global Climate Change, September 11, 1995

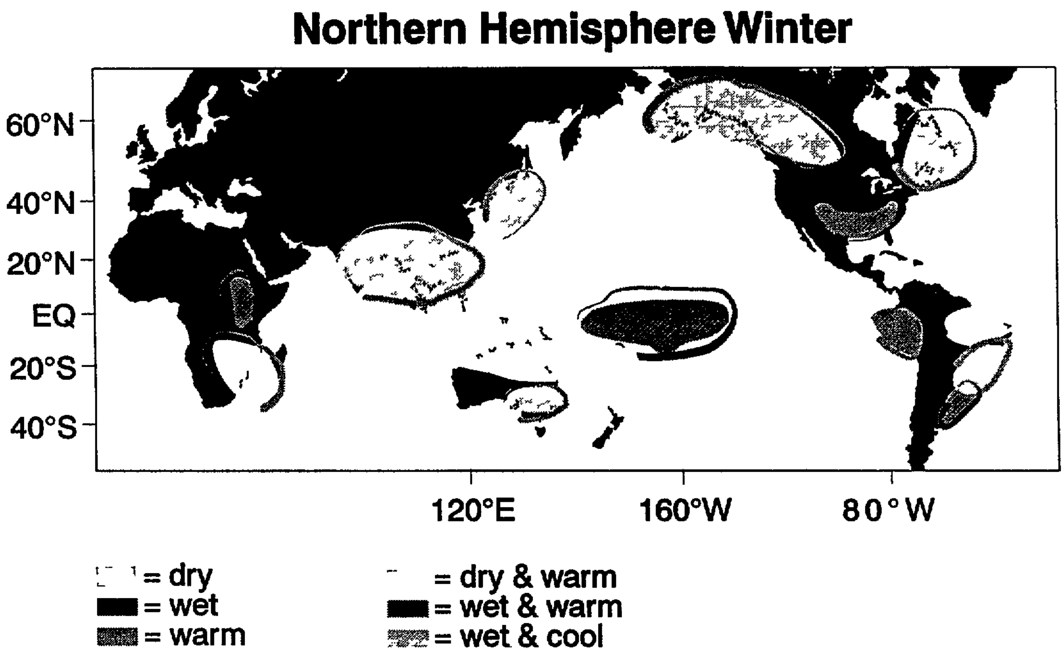

FIGURE 2 Pictoral representation of global climate impact anamolies due to ENSO (Provided by NOAA, based on work of C Ropelewski and collaborators)

Skin Cancer, Cataracts, and Immune Suppression

Ozone depletion can have both direct and indirect effects on ecological systems and human health Increased exposure to ultraviolet radiation (especially UV-B) can have harmful effects on photosynthesis (on land and sea), with potentially disruptive impacts on food production and the stability of ecosystems The most important direct human health effect would be an increase in nonmelanoma skin cancers, especially in fair-skinned populations Such cancers are already a major problem in the United States, with about 1 million new cases per year Furthermore, current models suggest a two percent increase in incidence for every one percent decrease in stratospheric ozone

The current scenario for phaseout of CFCs predicts a 25 percent increase in skin cancer by 2050 at 50°N latitude, relative to the 1980 incidence Melanoma is a less frequent but far more deadly skin cancer, whose relationship to UV-B exposure remains uncertain Both types of skin cancer have a long lag time between exposure and disease, the effects of increased UV-B may not be seen until after 2050 Increased UV-B can also be expected to increase the frequency of cataracts, which can lead to blindness in all populations Current estimates indicate a 0 3 to 0 6 percent increase in new cataract cases for every 1 percent decrease in stratospheric ozone Ozone depletion may also contribute to the frequency, severity, and duration of some infectious diseases due to ultraviolet's ability to suppress the immune system There are many uncertainties about the effect of UV-B on immune responses, although it appears that neither pigmentation nor sunscreens offer effective protection

Indirect Effects on Human Health

Food Production and Nutritional Health

Global climate change would have mixed effects on the productivity of agriculture, livestock, and fisheries In tropical and subtropical areas, global climate change may lead to droughts, flooding, and the emergence of new plant diseases, decreasing food production in many areas where food supplies are already insecure Meanwhile, crop productivity may increase in other regions, mostly in the higher temperate latitudes such as Canada, Siberia, and Patagonia However, agricultural projections are strongly dependent on assumptions about technological advances and patterns of consumption

Over 800 million people are chronically undernourished today, particularly in the developing world, and malnutrition is an underlying cause of childhood mortality With further population growth, malnutrition may increase the vulnerability of these populations to endemic diseases and epidemics Some areas may need to change crops, planting practices, and diet, further increasing vulnerability during the period of transition Such regions might be helped by advance warning of conditions that might cause crop failures

Overall, models project the world may be able to produce enough food to feed future populations However, changes in regional patterns of production could be significant, and in the long term, nutritional security can only be ensured through education and training, higher incomes, favorable market mechanisms, political stability, and population controls

Fresh Water Quality and Quantity

Great spatial and temporal variability characterize water availablility Climate change may exacerbate such variations Today 1 billion people lack access to clean and abundant drinking water, and even more are without adequate sanitation Adjustments to water shortages can be managed where physical infrastructure (reservoirs, pipelines, and canals) and water management institutions exist Increasing populations dependent on limited sources served by isolated systems are at more risk Landscapes may erode or stabilize as precipitation alters vegetative cover, thus affecting runoff and transport of sediment and pollutants

Air Pollution and Allergens

The same industrial processes that produce greenhouse gases will also produce increased urban air pollutants, and they too can pose major health risks Levels of fine particulates (from fossil fuels and wood smoke) and ozone (from photochemical reactions) are known to be associated with higher levels of hospital admissions for respiratory diseases Fine particulates also appear to be associated with admissions for heart disease and with general mortality In the United States, where air pollution is relatively low compared with Mexico City and some Asian cities, it nevertheless contributes to 70,000 excess deaths and 1 million additional hospitalizations annually In the future, as global increases in energy production lead to higher levels of particulates, and increases in temperature and ultraviolet radiation accelerate the reactions that produce ozone and other secondary pollutants, the health effects of air pollution on a global scale could be staggering Higher temperatures and humidity may also lead to higher concentrations of plant pollen and fungal spores that cause allergic disorders such as asthma and hay fever

Weather Disasters and Rising Sea Level

El Niño is associated with increased rainfall and floods in some regions Long-term climate change over the entire planet may result in an increase in extreme weather events, such as droughts, floods, and cyclones These events could increase the number of deaths and injuries and the incidence of infectious diseases and psychological disorders, as well as causing indirect effects through food shortages and the proliferation of disease vectors

A 40-centimeter rise in sea level would approximately double the number of people who are currently exposed to flooding each year in areas like Bangladesh It could also contribute to the loss of coastal and delta farmland, as in Egypt, and to the destruction of food supplies Rising sea level also increases the vulnerability of costal cities, low-lying areas, and small islands to damage during storms

Social and Demographic Dislocations

Global climate change would alter patterns of employment, wealth distribution, and population settlement throughout the world Physical conflicts might also arise over depleted environmental resources such as farmland, surface water, and coastal fisheries Biodiversity would also be affected (see Box 3) The greatest destabilizing effects would likely be experienced in areas of Africa which are already highly vulnerable At the same time, populations may be moving out of

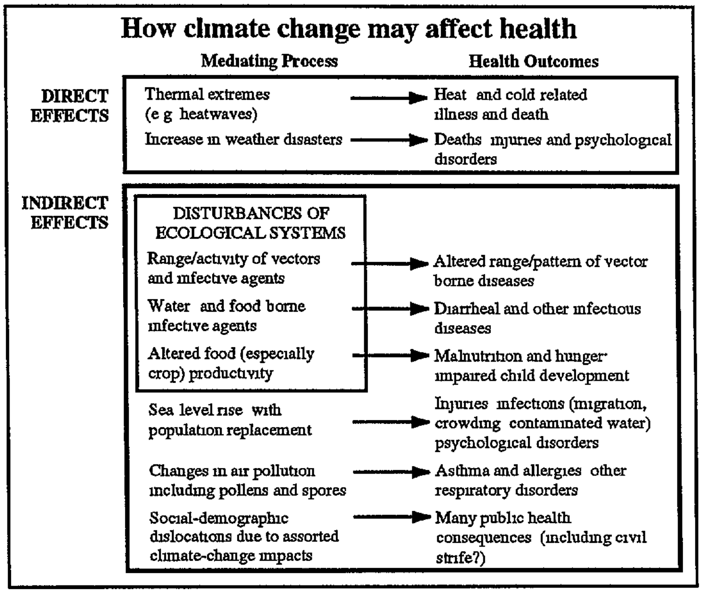

FIGURE 3 Ways in which global climate change may affect human health (Adapted from IPCC, 1995)

tropical and coastal areas and into cooler wilderness areas where they will be exposed to new and unfamiliar health threats

From another point of view, the difficulty of responding to global climate change lies in the rapid pace of the change—the projected rate of change is greater than has occurred on earth in the past 10,000 years Although it appears that some of the global climate changes may be dealt with by the industrial world, adaptation will be more difficult in the developing world The pace of global climate change may be complicated by an inadequate pace of institutional change

POLICY IMPLICATIONS

At the end of the first day of the conference, presentations were made on potential policy implications for health surveillance, disease prevention, and health professional education In addition, a special address was made by Brian Atwood, administrator of the Agency for International Development, on "Implications for International Cooperation" (see Box 4) These presentations served as background and introduction for the breakout and working group panel discussions that occurred on the second day, information from those presentations has been integrated into the panel reports that follow

Panel Reports

The second day of the conference was organized around six concurrent breakout and working group panels that considered the policy implications of global climate change and human health The six panels were (1) Global Surveillance and Response, (2) Disease Prevention, (3) Education for the Medical and Public Health Communities, (4) International Cooperation, (5) Research and Development Needs, and (6) Public Outreach and Risk Communication

These panels were asked to work from the assumption that global climate change would occur, and that its impacts on human health would be more or less as described in the foregoing discussion Working from that assumption, the panels were charged with addressing the question, "What do we do about it?" That is, what strategic actions could, and should, be taken to anticipate adverse health effects before they occur and to reduce or mitigate those effects when they do occur? In addition, the panels were asked to identify both short-term (1 to 5 years) and long-term (5 to 25 years) strategies

The following summaries reflect the individual group chairs' sense of the participants' discussion in their respective working groups, further illuminated by the material presented in plenary sessions on the preceding day

Global Surveillance and Response[3]

The emergence of new diseases and the reemergence of familiar diseases represent a serious threat to many regions and, indeed, in a shrinking world, to the entire human species In the future, therefore, it will be critical to have in place an integrated, worldwide surveillance and response mechanism for emerging infectious diseases The purpose of such a system would be to shorten the time between the detection of the first case and the implementation of effective measures for treatment, prevention, and control To the degree possible, therefore, it should also include surveillance for the various changes in climate and environment that may provide early warning signs of the possible outbreak of disease

The vital elements of such a system are (a) a rapid and comprehensive communications network, (b) accurate, reliable, laboratory-based diagnosis capabilities in host countries or regional centers, and (c) a mechanism for rapid response The functioning of this system would also be aided by heightened cooperation among national and international health organizations In the end, the creation of an integrated, worldwide system to monitor the occurrence and emergence of disease could become the most important international health policy initiative of the twenty-first century

The breakout panel reported that the most important problem in this area is the creation and maintenance of a critical mass of multidisciplinary expertise Short-term strategies to address this problem include personnel exchanges, cross-training, and the establishment of a Vice Presidential Fellowship Program Long-Term strategies include the encouragement of multidisciplinary training at all levels of relevant fields

The panel also endorsed earlier reports calling for the creation of an international consortium to address climate-related issues One difficulty in doing this is the need for political will and interagency and global coordination A short-term strategy would be to compile an inventory of existing resources and facilities that might become part of the effort, including sites and projects studying the environment and climate that could provide remote-sensing data and other indicators for health surveillance There was no consensus on which agency should serve as the focal point for this coordination within the United States, although the Centers for Disease Control and Prevention, the NAS, the IOM, and the interagency Committee on International Science Engineering and Technology (part of NSTC) were offered as candidates There was agreement, however, that the United States could not carry out this mission alone, it will be necessary to work with the resources, facilities, and institutions of other countries and international organizations

Finally, the importance of global surveillance and response was discussed as being critical to national security because military forces might need to be deployed to virtually any area of the world on short notice Knowledge of emerging diseases and their potential impact on military operations is of great importance in the preparation of countermeasures to avoid such threats, reduce their impact, and provide a rapid response to outbreaks

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[3]Dr Ruth Berkelman, deputy director, National Center for Infectious Diseases, Centers for Disease Control and Prevention, cochaired this panel and summarized their discussion and findings

Strategies (see also Table 3)

Short-term strategies
- Create and maintain a critical mass of multidisciplinary expertise
- Commission the NAS or the IOM to conduct a study of the problem

Long-term strategies
- Encourage multidisciplinary training at all levels of relevant fields

Disease Prevention[4]

The reemergence in the Americas of infectious diseases that had been controlled in the past, such as cholera, plague, and dengue, as well as the emergence of new infectious agents, such as Hanta and Guanarito viruses, *E coli* 0 157, and *cryptosporidia*, have had a direct impact on health policy and prevention efforts Over the past several years, governmental and nongovernmental organizations have been working closely to modify health policy to place more emphasis on disease prevention A major concern of these efforts are the changing dynamics of disease transmission, which are influenced by migration, land use, and environmental degradation

Many lines of action are being examined as ways to prevent diseases One requirement for any response will be flexible management within the health sector closest to the vulnerable population to allow it to adapt to changing patterns of disease In addition, the wide impact of infectious diseases such as AIDS requires a policy of increased intersectorial cooperation—that is, there must be fluid and open communication and management of health problems among health, environmental, and agricultural sections, supported by competent research that is based on careful policy analysis Participants believed that policy reform, combined with broad public support gained by effective use of the mass media, will allow us to confront the health problems caused by global climate change and environmental degradation

Policies for disease prevention and control usually involve three responses (1) removal of the hazardous exposure, (2) early detection (and investigation of the occurrence of diseases), and (3) treatment and control measures, such as prophylactic therapy Primary prevention might include vaccinating children or draining stagnant pools where mosquitoes breed In dealing with the health effects of global climate change, however, it would require preventing and even reversing greenhouse warming itself This kind of "preprimary" or "primordial" prevention would be desirable but was beyond the scope of this conference Nevertheless, there are still many actions that might be taken to mitigate the health effects of global climate change, especially in terms of anticipating what those effects will be and which populations are most at risk

Secondary prevention involves surveillance and early screening—the collection, analysis, and dissemination of pertinent data—and tertiary prevention involves responses—plans and facilities for rapid diagnosis and effective treatment to keep a disease from progressing Secondary and tertiary

[4]Dr Jonathan Patz, research associate, Johns Hopkins School of Public Health, cochaired this panel and summarized their discussion and findings

BOX 3 Ecology, Epidemiology and Climate Change*

Thomas E Lovejoy
Smithsonian Institution

Altered levels of greenhouse gases like CO_2 constitute an important environmental change by themselves in addition to those changes driven by the altered levels Field studies of the effects of elevated CO_2 on natural communities are limited at this point Bert Drake's two-species marsh community at the Smithsonian Environmental Research Center—the longest running field experiment—shows that plants with a C_4 photosynthetic pathway (e g , a sedge) have a definite competitive edge over C_3-pathway species (e g , a grass) Within a group of C_4 or C_3 plants, however, it is not possible to predict in advance how various species will respond to higher levels of CO_2 An initial study of part of a tree subjected to 2 months of elevated CO_2 in a Panamanian rainforest led to yellowing of its leaves and reduced photosynthesis It appears that the excessive accumulation of carbohydrates inhibits photosynthesis, with consequent high irradiation stress, photodamage, and loss of chlorophyll The rest of the tree seems incapable of drawing off the excess photosynthates This is, of course, different from a tree experiencing a CO_2 increase occurring over years and decades or a tree that grows up in a high-CO_2 environment

Of course, climate change will include not only CO_2 elevation but also changes in temperature regimes, rainfall, and other hydrological patterns There are almost no field experiments yet that combine more than a single one of these factors Nonetheless, it is clear from the above findings that it is a mistake to think of elevated CO_2 alone as a benign fertilizing factor for plants Rather, it is important to recognize that elevated CO_2 and associated climate change will instigate a cascade of effects that will ripple through natural communities with hard-to-envision epidemiological consequences

Paleoecological evidence relating to climate change during glacial/interglacial swings indicate rates of dispersal for plant species, especially trees, that are much slower (1/10th) than those projected by climate models It is simply not known whether species could move faster In addition, it is well known in North America and Europe, and to a lesser extent in the less studied tropics, that biological communities disassembled during those climate changes and different species moved at different rates and in different directions Ultimately, species assembled in communities of different composition The implications for epidemiology are difficult to envision, although worrisome

Climate change, whether human or naturally driven, will take place in landscapes that have been highly modified by human activity This will dramatically lower opportunities for dispersal and consequently generate considerable extinction of species—that is, a reduction in biological diversity

What are the implications for human health? It is hard to be precise and to provide a lot of detail Nonetheless, an abundance of changing relationships between species will undoubtedly affect epidemiology Some changes, of course, may be beneficial, but the balance are likely to be detrimental because weedy species such as white-tailed deer will be favored over nonweedy species It seems reasonable to anticipate epizootics and epidemics without any precedents

In addition, loss of biodiversity will impoverish the potential of biotechnology to contribute to the wealth of nations and will similarly diminish the potential of the life sciences to contribute to human health, wealth, and well-being

*Excerpts from a special briefing at the Conference on Human Health and Global Climate Change, September 11, 1995 prevention strategies are needed in most if not all nations However, the creation of a global surveillance and response capability will require unprecedented international collaboration, including a softening of the traditional boundaries between sectors, agencies, and nations Nongovernmental organizations and the media also have a important role to play in educating the population, without frightening them, and possibly changing some of their more destructive behaviors (see "Public Outreach and Risk Communication," p 24)

The breakout group recommended that prevention activities focus on anticipatory, rather than reactionary measures It identified six priority areas that overlap and incorporate those of other breakout groups

1 *targeted, integrated surveillance* that focuses on transitional zones and vulnerable populations,
2 *changes in medical education* that incorporate environmental health into curriculum and board exams,
3 *international cooperation* through information sharing and surveillance networks,
4 *methodological research* to evaluate prevention and intervention programs and to identify vulnerable populations, transition areas, and other risk factors,
5 *public education and outreach* aimed at policymakers as well as vulnerable popu-lations, especially children and the elderly, and
6 *public health infrastructure* to conduct (a) research and (b) vaccine and exposure reduction programs

Strategies (see also Table 3)

Short-term strategies

- Compile an inventory of existing resources and facilities to study the environment and climate that could provide remote-sensing data and other indicators for health surveillance

Long-term strategies

- Refocus or develop the public health infrastructure

Education for the Medical and Public Health Communities[5]

Despite increasing evidence that global climate change and ozone depletion may have serious consequences for human health, there is little understanding, both among policymakers and the public, of the extent of this potential threat Physicians and public health professionals should be central figures in helping to promote an understanding of the health effects associated with climate change, but they are by and large uninformed about the topic, as their education does not, in general, cover the relationship of global environmental change to human health

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[5]Dr Max Lum, director, Office of Health Communications, National Institute of Occupational Safety and Health, cochaired this panel and summarized their discussion and findings

Physicians, nurses, and other health professionals have a vital role to play in responding to the health effects of global climate change At present, however, physicians do not receive adequate training in occupational and environmental medicine, much less in the medical problems arising from global climate change, such as tropical diseases appearing in temperature zones In the United States, for example, although two-thirds of medical schools include occupational and environmental health in their curricula, the average student receives only 6 hours of exposure to these subjects over 4 years of study The situation is somewhat better in schools of public health Yet for both medical and public health students in the United States there is essentially no time available in the curriculum to address the potential human health consequences of global climate change For most professionals their principal source of information on global environmental health are articles in the scientific literature and conferences sponsored by nonprofit organizations

The breakout group agreed that health professionals should play a critical role in addressing the health effects of global climate change The central questions panelists posed were (a) what do health professionals already know, (b) what do they want to know, and (c) what should they know As a short-term strategy, the group recommended that the IOM and NAS conduct a study to identify core competencies and training mechanisms in the area of human health effects of global climate change, similar to a recent IOM study of environmental medicine (1995)

Global climate and health issues should be incorporated into medical board exams, reflecting the importance of this subject for the training of physicians The IOM and NAS might also broker efforts to promote faculty development in this area and to create centers of excellence in medical schools that would develop curricula in human health and global climate change The group also recommended conducting a study to identify existing government and industry programs that protect workers from the effects of ultraviolet exposure Such an activity could also increase awareness of the hazards of stratospheric ozone depletion

These efforts should be coordinated with those of professional, educational, and public service organizations Health professionals should also help in developing educational materials and in presenting information to policymakers and the general public to help increase understanding of the health implications of environmental policies These efforts should include the special needs of populations such as migrant workers and minorities that might not have adequate access to health care information In the long term, it will be important to monitor the effectiveness of these and other programs and, more importantly, to disseminate their results

Strategies (see also Table 3)

Short-term strategies

- Have the IOM or NAS conduct a study to identify core competencies and training mechanisms in the area of global environmental health, similar to a recent IOM study of environmental medicine
- Identify and study existing government and industry programs designed to protect workers from the effects of exposure to the sun

BOX 4 Implications for International Cooperation*

Brian Atwood
U S Agency for International Development

By working closely with our developing country partners, the U S Agency for International Development is able to facilitate the subtle but critically important changes that raise awareness of the threats of climate change and help to shape preventative and responsive measures Our work has informed other donors and encouraged them to invest in solutions we need Developing countries in particular are on the precipice of global environmental change They soon will be the leading source of greenhouse gas emissions, and the resulting climate change will take a heavy toll on their crowded coastal areas and fragile ecosystems The extraordinary biological wealth of these countries is already threatened by poorly planned development that undercuts the natural capital they and we need for the future

Energy consumption and one of its unwelcome by-products, pollution in the form of carbon emissions, are growing fastest in developing countries and in countries whose economies are in transition Developing countries are also experiencing rapid rates of deforestation and ecosystem degradation, which eliminates a primary sink for greenhouse gases For example, over the last decade, 154 million hectares of tropical forests, equivalent to more than three times the land area of France, have been lost to other uses The rate of that loss of biomass, especially in developing countries, is alarming

The resulting environmental degradations and misuse of natural resources create opportunities for new diseases, or old ones, to take hold We use the phrase "emerging diseases," yet for millions of people the new viruses have already emerged, and they have already claimed the lives of loved ones The word "emerging" simply does not convey the urgency we sense Only yesterday we were convinced that science had overcome the assault of these infectious diseases Advances in antibiotic drugs, vaccines against childhood diseases, and improved sanitation technology all seemed to be winning the day The incidence of polio, whooping cough, and diphtheria were declining Fast-acting antibiotics reduced the threat of meningitis and bacterial pneumonia But we now know that our euphoria was premature We did not take into account the extraordinary resilience of infectious microbes, which have a remarkable ability to evolve, adapt, and develop resistance to drugs Thus, diseases that were once thought to be under control have reemerged There are many of these reemerging diseases, and they just do not appear only in the developing world nowadays We find them in New Mexico, in Minnesota, in Virginia, and in New York Around the world there is a resurgence of cholera, malaria, and yellow fever, often in drug-resistant forms And of course, there is HIV and AIDS

We believe that global problems must be resolved at the local level We know that these efforts must be aided by new breakthroughs in science and technology Investment in research is essential if we are to keep up with the effects of ecological change The battles we must fight against new microbes, new forms of crop blight, the spread of desertification new forms of pestilence, and the rapid population growth make research more important than ever We face a dynamic, rapidly accelerating set of new challenges, yet we are at risk of falling desperately behind the curve, as the changes we advertently and inadvertently introduce run far ahead of our resources and our knowledge base Research is not like tap water It cannot be turned off and on again without serious consequences To be successful in these efforts,

Continued

Excerpts from remarks at the Conference on Human Health and Global Climate Change, September 11, 1995

BOX 4 *Continued*

governments must continue their support of the scientific community This will require considerable efforts by federal agencies, by our university partners, and by nongovernmental organizations The private sector is our natural partner However, it does not cover the entire spectrum of research

It is dangerous to assume that the unfettered hand of Adam Smith will lead to the investments we need to deal with international health and environmental threats to the United States That will require a coherent and cost-effective foreign assistance program backed by sound policies and global cooperation We are uniquely placed as a nation to help the rest of the world meet these challenges Our quality of life in the next century will be determined in large measure by how we meet the global challenges of today Science and technology give us the tools we will need to meet the challenges of tomorrow

Long-term strategies

- Monitor the effectiveness of these and other programs and, more importantly, disseminate their results
- Incorporate questions about climate-related health issues on medical board examinations

International Cooperation[6]

Global climate change is believed to cause a wide variety of deleterious effects including desertification, changes in agricultural patterns, and disease These effects are both direct and indirect, and the causes may be either natural or manmade To the extent that global climate change and its impacts are influenced by human activity, methods must be found to mitigate, adapt to, or respond to them The U S government is obligated to exercise leadership at home and abroad to ensure that responses are appropriate and timely

Every human being is vulnerable to the effects of global climate change, but the citizens of developing countries and regions face the most immediate dangers In those areas, both climatic change and the need for responses to it may be greatest, but the available resources for addressing them is most limited Clearly, the preventive and responsive measures we use to deal with global climate change and its effects must involve every affected person and operate society-wide

The breakout panel reported that many of the necessary systems and networks for international cooperation are already in place—the United Nations Environmental Programme, the World Health Organization, UNICEF, and networks of collaborating centers What is required is improved coordination among existing systems to place the health effects of global climate change on their respective agendas and to ensure a two-way flow of information among them The panel found a particular need to improve the links between agencies and organizations that conduct climate forecasting, health planning, health surveillance, and the implementation of health programs

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[6]Dr Rudi Slooff, Division of Environmental Health, World Health Organization, cochaired this panel and summarized their discussion and findings

One short-term strategy would be to incorporate health effects monitoring and reporting into existing global climate change activities, such as the Framework Convention on Climate Change program and the United Nations-sponsored "Climate Agenda" Another strategy would be to look for the health effects of global climate change in the information already gathered for the ongoing U S Country Study Program These efforts will be ineffective, however, unless they are accompanied by increased efforts to provide relevant information to national and international policymakers

In the long term, the panel recommended that global climate change and health issues be incorporated into sustainable development planning, not only by individual nations, but also by the World Bank, the United Nations Development Program, the Food and Agriculture Organization, and similar organizations By the same token, health and climate planning should be broadened to include related environmental issues such as biodiversity This, in turn, requires that stakeholders have better access to the information gathered, analyzed, and disseminated by the global surveillance system discussed by other breakout panels

Strategies (see also Table 3)

Short-term strategies

- Incorporate health effects monitoring and reporting into existing global climate change programs
- Look for the health effects of global climate change in the information already gathered for other programs

Long-term strategies

- Incorporate global climate change and health issues into sustainable development planning, not only by individual nations, but also by the World Bank, the United Nations Development Program, the Food and Agriculture Organization, and similar organizations
- Broaden health and climate planning to include environmental issues such as biodiversity

Research and Development Needs[7]

Rather than enumerate the many specific research topics that need to be addressed, the breakout panel emphasized the need for an integrated, interdisciplinary R&D program that will encourage collaboration among experts and organizations from a wide range of fields and disciplines Achieving this will probably require a concerted effort to overcome the boundaries that currently separate scientific disciplines, research institutions, budgetary programs, funding agencies, and international sponsors In the United States, for example, funding would probably come from a consortium of federal agencies rather than from a series of small, fragmented programs

The research problems addressed by this program should include climatic variations that already pose health risks, as well as future effects of global climate change

[7]Dr David Rall, foreign secretary, Institute of Medicine, cochaired this panel and summarized their discussion and findings

Strategies (see also Table 3)

Short-term strategies

In the short term, the panel proposed that the program undertake pilot projects involving case studies that integrate three sets of variables

1 *infectious diseases* (e g , cholera, dengue, malaria, and Lyme disease),

2 *mechanisms of susceptibility* (e g , UV-B and immune suppression, fine particulates, and cardiovascular or pulmonary disease), and

3 *global change drivers* that might exacerbate or mitigate these problems (e g , population growth, economic development, and urbanization)

Possible models for these case studies are the Technical and Scientific Assessment and the United Nations Intergovernmental Panel on Climate Change The case studies themselves could be performed by international organizations, by private groups, or by the IOM or NAS

Long-term strategies

The long-term goals of this program would be to identify and address gaps in current knowledge, and to disseminate and apply the lessons learned from the case studies

Public Outreach and Risk Communication[8]

Despite a wealth of scientific studies and technical information, the general public is not well informed on the relationship between global climate change and human health Several participants made the analogy to the difficulties of informing the public about the dangers of nuclear war Such information is highly technical, far removed from the common experience, disconcerting to contemplate, and often undermined by a vocal opposition As a result, the first step in any outreach campaign would be to assess the information (and disinformation) that is already available to determine what further steps might be appropriate

The breakout panel endorsed the principles of risk communication that are embodied in the 10-step strategy outlined in Table 2 The primary long-term goals of this strategy are (1) involving the public by encouraging awareness and discussion, and (2) building bridges between the medical and environmental communities In both cases, the panel recommended working through existing networks and infrastructures, initially targeting opinion leaders but making use of the full range of formal and informal intermediaries to reach broader audiences—not only churches and newspaper editors, for example, but also Boy/Girl Scouts and television weathermen, as well as medical associations, senior citizens' associations, and schools

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[8]Dr William Farland, director, National Center for Environmental Assessment, Environmental Protection Agency, cochaired this panel and summarized their discussion and findings

TABLE 2 Developing a Risk Communication Strategy for Global Climate Change

Step 1	**Review background information** (What messages are already out there?)
Step 2	**Set communication objectives** (What do we want to accomplish?) Example Increase public awareness about the public health implications of global climate change
Step 3	**Analyze and segment target audiences** (Whom do we want to reach?) Example Construct communications based on audience attitudes
Step 4	**Develop and pretest message concepts** (What do we want to say?)
Step 5	**Select communication channels** (Where do we want to say it?)
Step 6	**Create and pretest messages and products** (How do we want to say it?)
Step 7	**Develop a promotion plan** (How do we get it used?)
Step 8	**Implement communication strategies and conduct a process evaluation** (Let's do it!)
Step 9	**Conduct outcome and impact evaluations** (How well did we do?)
Step 10	**Feedback to improve communication effectiveness** (Where do we go from here?)

Strategies (see also Table 3) The panel identified the following short-term action items, which might serve as the foundation for long-term efforts

- Identify, contact, and infuse existing networks with health concerns related to global climate change Use these networks as a feedback mechanism to find out what further information the public wants or needs
- Distill the information generated by the present conference for dissemination through journal articles, editorials, op-ed pieces, targeted brochures, public service announcements, informational videos, or a home page on the World Wide Web
- Establish a volunteer group or forum to continue the communication activities suggested or actually begun during the present conference
- Develop a response capability to counter disinformation

SUMMARY OF PRIORITIES AND STRATEGIES

Participants voiced a clear message throughout the conference Changes in global climate would pose substantial risks to human health, both in the near and long-term They also hoped that their efforts would help mobilize opinion and action toward the implementation of strategies that would occur as far "upstream" as possible

Conference participants identified and described a number of actions that could be taken to address these potential threats These strategies are summarized in Table 3 and share certain common threads

- identify and work with existing resources, facilities, networks, and information,
- encourage greater coordination and collaboration among relevant organizations, disciplines, nations, and funding agencies,
- create from these institutions and funding sources an integrated worldwide network for surveillance and response to indicators of global climate change and emerging diseases,
- support multidisciplinary research to determine linkages among global climate change, food production, and human health,
- provide appropriate training for researchers and health professionals, including the creation of centers of excellence and the enhancement of faculty, and
- establish information and outreach programs

TABLE 3 Summary of Suggested Strategies Emanating from the Working Group Sessions

Implications for	Short-Term Strategies	Long-Term Strategies
Global surveillance and response	Create and maintain a critical mass of multidisciplinary expertise	Encourage multidisciplinary training at all levels of relevant fields
	Commission the National Academy of Sciences (NAS) or the Institute of Medicine (IOM) to conduct a study of the problem	
Disease prevention	Compile an inventory of existing resources and facilities to study the environment and climate that could provide remote-sensing data and other indicators for health surveillance	Refocus or develop the public health infrastructure
Education for the medical and public health communities	Have the IOM or NAS conduct a study to identify core competencies and training mechanisms in the area of global environmental health, similar to a recent IOM study of environmental medicine	Monitor the effectiveness of these and other programs and, more importantly, disseminate their results
	Identify and study existing government and industry programs designed to protect workers from the effects of exposure to the sun	Incorporate questions about climate-related health issues on medical board examinations
International cooperation	Incorporate health effects monitoring and reporting into existing global climate change programs	Incorporate global climate change and health issues into sustainable development planning, not only by individual nations, but also by the World Bank, the United Nations Development Program the Food and Agriculture Organization, and similar organizations
	Look for the health effects of global climate change in the information already gathered for other programs	
		Broaden health and climate planning to include environmental issues such as biodiversity
Research and development (R&D) needs	Create an integrated, interdisciplinary R&D program that would encourage collaboration among experts and organizations from a wide range of fields and disciplines Such a program would undertake pilot projects involving case studies that integrate (a) infectious and other diseases, (b) mechanisms of susceptibility, and (c) global change drivers that might exacerbate or mitigate these problems	Identify and address gaps in current knowledge, and disseminate and apply the lessons learned from the case studies
Public outreach and risk communication	Establish a volunteer group or forum to continue the communication activities identified and discussed at this conference	(a) Involve the public by encouraging awareness and discussion, and (b) build bridges between the medical and environmental communities

References and Further Reading

The ınterested reader can find more detaıled ınformatıon about the topıcs covered by thıs conference by referrıng to the followıng publıcatıons

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APPENDIX A

National Science and Technology Council (NSTC) Sponsoring Members, Interagency Working Group, Institute of Medicine (IOM) Steering Committee, and Staff

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U S Department of Defense
U S Department of Energy
U S Global Change Research Program
U S Agency for International Development

NSTC INTERAGENCY WORKING GROUP

Maurice Averner, Advanced Life Support, Life and Biomedical Sciences and Applications Division, National Aeronautics and Space Administration, Washington, DC
Lois Beaver, Office of External Affairs, Food and Drug Administration, Rockville, MD
Rosina Bierbaum, Environment Division, Office of Science and Technology Policy, Executive Office of the President, Washington, DC
Jim Buizer, Office of Global Programs, National Oceanic and Atmospheric Administration, Silver Spring, MD
Dennis Carroll, Office of Health and Nutrition, Agency for International Development, Washington, DC
Jack C Chow, Division of International Relations, Fogarty International Center, National Institutes of Health, Bethesda, MD
Robert Corell, Geosciences Division, National Science Foundation, Arlington, VA
Jackie Dupont, Agricultural Research Service, U S Department of Agriculture, Beltsville, MD
Elaine Esber, Center for Biologics Evaluation and Research, Food and Drug Administration, Rockville, MD
Gary Evans, Office of the Secretary, U S Department of Agriculture, Washington, DC
Mike Finley, Office of External Relations, Pan American Health Organization, Washington, DC
Karen Gallegos, Office of Global Programs, U S Department of State, Washington, DC

Luiz Galvao, Division of Health and Environment, Pan American Health Organization, Washington, DC

Mary Gant, National Institute of Environmental Health Sciences, National Institutes of Health, Bethesda, MD

Ann Grambsch, Climate Change Bureau, Office of Policy, Planning, and Evaluation, Environmental Protection Agency, Washington, DC

Duane Gubler, Vector Borne Infectious Diseases Division, Centers for Disease Control and Prevention, National Center for Infectious Diseases, Fort Collins, CO

Debbie Hanfman, Science Division, Office of Science and Technology Policy, Executive Office of the President, Washington, DC

Col Jerry Jaax, United States Army, Medical Research and Materiel Command, Ft Detrick, MD

Carla Kappell, Office of Energy, Environment, and Technology, Bureau of Global Programs, Field Support, and Research, Agency for International Development, Washington, DC

Hiram Larew, Office of Policy and Evaluation, Agency for International Development, Washington, DC

Orville Lavander, Nutrient Requirements and Functions Laboratory, Agricultural Research Service, U S Department of Agriculture, Beltsville, MD

Alexandra Levitt, Office of Science, Technology and Health, U S Department of State, Washington, DC

Ed Malloy, Office of Science, Technology, and Health, U S Department of State, Washington, DC

Patrick McConnon, Centers for Disease Control and Prevention, Atlanta

Mike McCracken, U S Global Change Research Program, Washington, DC

Roscoe M Moore, Development Support and African Affairs, Office of International Health, U S Department of Health and Human Services, Rockville, MD

Jonathan Patz, Johns Hopkins School of Public Health, Environmental Protection Agency, Office of Policy, Planning, and Evaluation, Climate Change Division, Washington, DC

Karen Peterson, Division of International Relations, Fogarty International Center, National Institutes of Health, Bethesda, MD

Hernan Rosenberg, Office of External Relations, Pan American Health Organization, Washington, DC

David Sandalow, Council on Environmental Quality, Executive Office of the President, Washington, DC

Joel Scheraga, Climate Change Bureau, Office of Policy, Planning, and Evaluation, Environmental Protection Agency, Washington, DC

Artie Shelton, Office of Allergy, Immunology and Oncology, U S Department of Veterans Affairs, Washington, DC

Phillip L Sims, Agriculture Research Service, U S Department of Agriculture, Beltsville, MD

Anthony Socci, U S Global Change Research Program, Washington, DC

Macol Stewart, Office of Global Programs, National Oceanic and Atmospheric Administration, Silver Spring, MD

Col Ernie Takafuji, U S Army Medical Research Institute for Infectious Diseases, Fort Detrick, MD

David Thomassen, Office Health and Environment Research, Office of Energy Research, U S Department of Energy, Washington, DC

Beth Viola, Council on Environmental Quality, Executive Office of the President, Washington, DC

Robert Watson, Environment Division, Office of Science and Technology Policy, Executive Office of the President, Washington, DC

Catherine Woteki, Science Division, Office of Science and Technology Policy, Executive Office of the President, Washington, DC

INSTITUTE OF MEDICINE/NATIONAL ACADEMY OF SCIENCES STEERING COMMITTEE

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Human Health and Global Climate Change, Division of Health Sciences Policy

Karen Hein, executive officer, Institute of Medicine

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Loren Setlow, director, Polar Research Board, National Academy of Sciences

Valerie Setlow, director, Division of Health Sciences Policy, Institute of Medicine

Kenneth Shine, president, Institute of Medicine

William Sprigg, director, Board on Atmospheric Sciences and Climate, David

David Westbrook, manager, Federal Contracts, National Academy of Sciences National Academy of Sciences

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Rosina Bierbaum, senior policy analyst
Jack Gibbons, assistant to the president for science and technology
Brett Orlando, intern
Jason Randall, intern
Robert Watson, associate director for environment

APPENDIX B

Conference Agenda

Conference on Human Health and Global Climate Change
The National Science and Technology Council, the Institute of Medicine, and the National Academy of Sciences

September 11–12, 1995

National Academy of Sciences
Main Auditorium
2101 Constitution Avenue, N W
Washington, DC 20418

AGENDA

MONDAY, SEPTEMBER 11, 1995

7 30–9 00 a m — **REGISTRATION**

9 00–9 10 a m — **WELCOMING REMARKS**

Kenneth I Shine, M D
President, Institute of Medicine

John H Gibbons, Ph D
Assistant to the President for Science and Technology

9 10–9 50 a m — **PANEL I OVERVIEW**
Kenneth I Shine, M D (*Chair*)
President, Institute of Medicine

The Science and Impacts of Climate Change and Ozone Depletion
Robert Watson, Ph D
Associate Director for the Environment, Office of Science and Technology Policy
Executive Office of the President

Climate Change and Human Health Risks
Anthony McMichael, Ph D
Professor of Epidemiology, London School of Hygiene and Tropical Medicine

9 50–10 10 a m — **QUESTION AND ANSWER SESSION**

10 10–11 10 a m	**PANEL II CLIMATE CHANGE AND INFECTIOUS DISEASES** **Mary E Wilson, M D** (*Panel Chair*) Assistant Professor, Harvard University *Vector-Borne Diseases* **Duane Gubler, Sc D** Centers for Disease Control and Prevention *Marine Ecosystems* **Rita Colwell, Ph D , M S** President, American Association for the Advancement of Science *Emerging and Reemerging Diseases* **Steven Morse, Ph D** Assistant Professor of Virology, Rockefeller University
11 10–12 00 p m	**QUESTION AND ANSWER SESSION**
12 00–12 30 p m	**LUNCH (Provided in the Great Hall)**
12 30–1 00 p m	**SPECIAL BRIEFING** *El Niño Analogue for Long-Term Climate Change* **J Michael Hall, Ph D** Director, Office of Global Programs, National Oceanic and Atmospheric Administration **Paul Epstein, M D , M P H** Harvard Medical School
1 00–1 30 p m	**PANEL III DIRECT HEALTH EFFECTS FROM CLIMATE CHANGE AND OZONE DEPLETION** **Terri Damstra, Ph D** (*Panel Chair*) Deputy Director, National Institute of Environmental Health Sciences *Climate Change and Heat Stress* **Larry Kalkstein, Ph D** Professor of Geography, University of Delaware *Ozone Depletion and Its Health Effects Skin Cancer Cataracts and Immune Suppression* **Margaret Kripke, Ph D , M A** Professor and Chairman, University of Texas M D Anderson Cancer Center
1 30–2 00 p m	**QUESTION AND ANSWER SESSION**

2 00–2 45 p m	**PANEL IV INDIRECT HEALTH EFFECTS OF CLIMATE CHANGE**
	Andrew Haines, M D (*Panel Chair*) Professor of Primary Care, University of London Medical School
	Impacts on Nutritional Health **David Oot, Ph D** Director, Office of Nutrition and Health, United States Agency for International Development
	Impacts on Fresh Water Quality and Quantity **Reds Wolman, Ph D , M A** Professor of Geography, Johns Hopkins University
	Impacts on Air Quality **Joel Schwartz, Ph D** Professor of Environmental Epidemiology, Harvard University
2 45–3 15 p m	**QUESTION AND ANSWER SESSION**
3 15–3 30 p m	**COFFEE BREAK**
3 30–4 00 p m	**SPECIAL ADDRESS**
	Implications for International Cooperation **Mr J Brian Atwood** Administrator, United States Agency for International Development
4 00–4 30 p m	**INTRODUCTION OF KEYNOTE SPEAKER** **John H Gibbons, Ph D** Assistant to the President for Science and Technology
	KEYNOTE ADDRESS *The Interplay of Climate Change Ozone Depletion and Human Health* **Albert Gore, Jr , Vice President of the United States**
4 30–5 15 p m	**PANEL V POLICY IMPLICATIONS**
	Anne Solomon, M P A (*Panel Chair*) Deputy Assistant Secretary for Science, Technology and Health, Department of State
	Implications for Global Health Surveillance and Response **Stephen Joseph, M D , M P H** Assistant Secretary for Health Affairs Department of Defense
	Implications for Disease Prevention **Sir George A O Alleyne, M D** Director, Pan American Health Organization

	Implications for Education in the Medical and Public Health Communities **Eric Chivian, M D** Chair, Physicians for Social Responsibility
5 15–5 45 p m	**QUESTION AND ANSWER SESSION**
5 45–6 00 p m	**WRAP UP, INSTRUCTIONS FOR THE NEXT DAY**
6 00 p m	**ADJOURN**
6 15 p m	**RECEPTION—GREAT HALL**

<u>**TUESDAY, SEPTEMBER 12, 1995**</u>

7 00–8 00 a m	**CONTINENTAL BREAKFAST-NAS GREAT HALL**
8 00–9 00 a m	**BREAKOUT SESSION COCHAIRS CONVENE TO DISCUSS GOALS AND STRATEGIES**
9 00–9 15 a m	**MORNING PLENARY** *Charge to Breakout Groups* **Bernard Goldstein, M D** (*Chair*)
9 15–12 30 p m	**BREAKOUT GROUP SESSIONS** **GROUP 1 IMPLICATIONS FOR GLOBAL HEALTH SURVEILLANCE AND RESPONSE** **Ruth Berkleman, M D** (*Government Cochair*) Deputy Director, National Center for Infectious Diseases, Centers for Disease Control and Prevention **Demisse Habte, M D** (*Nongovernment Cochair*) Director, Centre for Health and Population Research **GROUP 2 IMPLICATIONS FOR DISEASE PREVENTION** **Sheila Newton, Ph D** (*Government Cochair*) Coordinator for Environment, Disease Prevention and Health Promotion, Department of Health and Human Services **Jonathan Patz, M D , M P H** (*Nongovernment Cochair*) Johns Hopkins University

GROUP 3 IMPLICATIONS FOR EDUCATION OF THE MEDICAL AND PUBLIC HEALTH COMMUNITIES

Max Lum, Ed D , M P A (*Government Cochair*)
Director, Office of Health Communications, National Institute of Occupational Safety and Health

Bernard Goldstein, M D (*Nongovernment Cochair*)
Chair, Department of Environmental and Community Medicine, Robert Wood Johnson School of Medicine

GROUP 4 IMPLICATIONS FOR INTERNATIONAL COOPERATION

Rafe Pomerance (*Government Cochair*)
Deputy Assistant Secretary for the Environment and Development, State Department

Rudi Slooff, Ph D (*Nongovernment Cochair*)
Division of Environmental Health, World Health Organization

GROUP 5 IMPLICATIONS FOR RESEARCH AND DEVELOPMENT NEEDS

Robert Corell, Ph D (*Government Cochair*)
Chair, Subcommittee on Global Change Research and Development, United States Global Change Research Program

David P Rall, M D , Ph D (*Nongovernment Cochair*)
Foreign Secretary, Institute of Medicine

GROUP 6 IMPLICATIONS FOR PUBLIC OUTREACH AND RISK COMMUNICATION

Bill Farland, Ph D (*Government Cochair*)
Director of National Center for Environmental Assessment, Environmental Protection Agency

Thomas Malone, Ph D (*Nongovernment Cochair*)
Director of Sigma Xi Center's Human Development Program

12 30–1 00 p m **LUNCH (PROVIDED IN THE GREAT HALL)**

1 00–1 30 p m **SPECIAL ADDRESS**

Biodiversity Climate Change and Human Health
Thomas Lovejoy, Ph D
Counselor to the Secretary for Biodiversity and Environmental Affairs, Smithsonian Institution

1 30–3 30 p m **CLOSING PLENARY**

Bernard Goldstein, M D (*Plenary Chair*)
Chair, Department of Environmental and Community Medicine,
Robert Wood Johnson School of Medicine

Breakout group Cochairs report on strategies for addressing potential health effects of global climate change developed during their discussions

3 00–4 00 p m **OPEN DISCUSSION**

4 00 p m **ADJOURN**

APPENDIX C

Speakers, Authors, Chairs, and Conference Registrants

SPEAKERS

George A O Alleyne
Director
Pan American Health Organization

J Brian Atwood
Administrator
United States Agency for International Development

Eric Chivian
Physicians for Social Responsibility

Rita Colwell
President
American Association for the Advancement of Science

Terri Damstra
Acting Deputy Director
International Programs
National Institute of Environmental Health Sciences

Paul Epstein
Harvard Medical School

John H Gibbons
Assistant to the President for Science and Technology

Bernard Goldstein
Director
Environmental and Occupational Health Sciences Institute
UMDNJ-Robert Wood Johnson Medical School

Albert Gore, Jr
Vice President
United States of America

Duane Gubler
Director
Division of Vector Borne Infectious Diseases
Centers for Disease Control and Prevention

Demisse Habte
Director
Centre for Health and Population Research

Andrew Haines
Professor of Primary Care
University of London Medical School

J Michael Hall
Director
Office of Global Programs
National Oceanic and Atmospheric Administration

Stephen Joseph
Assistant Secretary for Health Affairs
U S Department of Defense

Larry Kalkstein
Department of Geography
University of Delaware

Margaret Kripke
Department of Immunology
Anderson Cancer Center

Thomas E Lovejoy
Secretary for Biodiversity and Environmental Affairs
Smithsonian Institution

Max Lum
Associate Director for Health Communications
National Institute for Occupational Safety and Health

Anthony McMichael
Department of Epidemiology and Population Science
London School of Hygiene and Tropical Medicine

Steven Morse
Associate Professor
Rockefeller University

David Oot
Director
Office of Nutrition and Health
United States Agency for International Development

Ari Patrinos
Associate Director
Office of Health and Environmental Research
U S Department of Energy

David Rall
Foreign Secretary
Institute of Medicine

Joel Schwartz
Associate Professor
Environmental Epidemiology Program
Harvard University School of Public Health

Kenneth I Shine
President
Institute of Medicine

Rudi Slooff
Division of Environmental Health
World Health Organization

Anne Soloman
Deputy Assistant Secretary of Science Technology and Health
U S Department of State

Robert Watson
Associate Director for the Environment
Office of Science and Technology Policy
Executive Office of the President

Mary E Wilson
Assistant Professor
Harvard University

M Gordon "Reds" Wolman
Professor of Geography
Johns Hopkins University

AUTHORS

John M Balbus-Kornfeld
Assistant Professor of Medicine
George Washington University

Ann Bostrom
School of Public Policy
Georgia Institute of Technology

Eric Chivian
Assistant Clinical Professor
Department of Psychiatry
Harvard Medical School

Paul R Epstein
Professor
The Cambridge Hospital
Harvard University Medical School

Duane Gubler
Director
Division of Vector Bourne Infectious Diseases
Center for Disease Control and Prevention

James A Harrell
Deputy Director
Office of Disease Prevention and Health Promotion
Public Health Service

Hiram Larew
Policy Specialist
Agency for International Development

Jonathan A Patz
Research Associate
Johns Hopkins School of Public Health

Warren T Piver
Adjunct Professor
National Institute of Environmental Health Sciences

Marla Salmon
Director
Division of Nursing
Department of Health and Human Services

Rudi Slooff
Division of Environmental Health
World Health Organization

Tim Tinker
Health Education Specialist
Agency for Toxic Substances and Disease Registry

Continued

CHAIRS

Ruth L Berkleman
Deputy Director
National Center for Infectious Disease
Centers for Disease Control and Prevention

Robert W Corell
Subcommittee on Global Change
Research and Development
U S Global Change Research Program

Terri Damstra
Acting Deputy Director
International Programs
National Institute of Environmental
Health Sciences

William H Farland
Director
National Center for Environmental
Assessment
Environmental Protection Agency

Bernard D Goldstein
Director
Environmental and Occupational Health
Sciences Institute
Robert Wood Johnson Medical School

Demisse Habte
Director
Center for Health and Population Research

Andrew Haines
Professor of Primary Health Care
University College of Middlesex

Max Lum
Director
Office of Health Communications
National Institute of Occupational
Safety and Health

Thomas F Malone
Founding Director
The Sigma Xi Scientific Research Society

Sheila A Newton
Coordinator for the Environment
Office of Disease Prevention and Health
Promotion, Public Health Service

Jonathan A Patz
Research Associate
Johns Hopkins School of Public Health

Rafe Pomerance
Deputy Assistant Secretary for
Environment and Development
U S Department of State

David P Rall
Foreign Secretary
Institute of Medicine

Kenneth I Shine
President
Institute of Medicine

Anne K Solomon
Deputy Assistant Secretary for
Science, Technology and Health
U S Department of State

Rudi Slooff
Division of Environmental Health
World Health Organization

Mary E Wilson
Assistant Professor
Harvard University

CONFERENCE REGISTRANTS

Philip H Abelson
American Association for the Advancement of Science

Frank Addivinold
University of Maryland

Sir George A O Alleyne
Pan-American Health Organization

Arlene F Anderson
U S Department of Energy

Neil Anderson
National Science Foundation

Sherrod Anderson
U S Department of Transportation

Joan L Aron
Johns Hopkins School of Hygiene and Public Health

J Brian Atwood
Agency for International Development

Maurice Averner
National Aeronautics and Space Administration

Sue Bachtel
Office of Science and Technology Policy

D James Baker
National Oceanic and Atmospheric Association

Judith Bale
National Research Council

John M Balbus-Kornfeld
George Washington University

William Bancroff
U S Army Medical Research and Materiel Command

David Banks
American Petroleum Institute

Eric J Barron
Pennsylvania State University

Gerald S Barton
National Oceanic and Atmospheric Association

James R Beall
U S Department of Energy

Lois Ann Beaver
Food and Drug Administration

Melinda A Beck
University of North Carolina

Dan Becker
Sierra Club

Yvette Benjamin
Institute of Medicine

Gershon Bergeisen
Environmental Protection Agency

Ruth L Berkleman
Centers for Disease Control and Prevention

David Bernstein
Universal Healthwatch

Brent Berwager
Center for Health and Population Affairs

Rosina Bierbaum
Office of Science and Technology Policy

Eugene W Bierly
American Geophysical Union

David Blockstein
Institute for the Environment

Paul M Bloom
Tufts University

Fred Blosser
Environmental Protection Agency

Genia D Bohrer
National Institute of Environmental Health Sciences

John Borazzo
Agency for International Development

Ann Bostrom
Georgia Institute of Technology

Colin L Bradford, Jr
Agency for International Development

Lynn Bradley
Association of State and Territorial Health Officers

David Brandling-Bennet
Pan American Health Organization

Bryna Brennan
Pan American Health Organization

Mary J Brooks
Greencool

Allen Buckingham
American Association of Retired Persons

Jim Buizer
National Oceanic and Atmospheric Administration

Joy E Carlson
Children's Environmental Health Network

Gregory R Carmichael
Center for Global and Regional Environment

Fran Carr
Agency for International Development

Michael D Carr
U S Department of Interior

Willine Carr
Grantmakers in Health

Dennis Carroll
Agency for International Development

James C Cecil
The Pentagon

D W Chen
Health Resources and Services Administration

Shouquan Cheng
University of Delaware

Mary Ann Childs
Universal Healthwatch, Inc

Eunyong Chung
U S Agency for International Development

Christopher Chyba
Princeton University

Eric Chivian
Harvard University Medical School

David L Clark
University of Wisconsin, Madison

Emery T Cleaves
Geological Society of America

Daniel G Colley
Centers for Disease Control and Prevention

Rita R Colwell
University of Maryland

Nugent Conn
Liberty Tree Alliance

Elizabeth Cook
World Resources Institute

Leslie B Cordes
Agency for International Development

Anthony Cortese
Consortium for Environmental Education in Medicine

Robert W Corell
U S Global Change Research Program

Lisa Cruz-Avalos
Nurse Consultant

Owen Cylke
Tata Energy and Resources Institute

John Daly
Agency for International Development

Terri Damstra
National Institute of Environmental Health Sciences

David Danzig
Sierra Club

Frances R Davidson
U S Agency for International Development

Tudor T Davies
Environmental Protection Agency

Joe Davis
Environmental Health Center

Molly Davis
U S Agency for International Development

Edward C DeFabo
George Washington University

Henrietta DeGroot
U S Department of Transportation

Linda DePugh
Institute of Medicine

Dennis J Devlin
Exxon Biomedical Sciences, Inc

Angela Phillips Diaz
Office of Science and Technology Policy

Vanessa Dixon
American Association of Retired Persons

Andrew Dobson
Princeton University

Jordana Dolowich
Council on Environmental Quality

Meg Doskin
Physicians for Social Responsibility

Thomas F Downham II
American Academy of Dermatology

Robert Drew
American Petroleum Institute

Bernadette Dunham
American Veterinary Medical Association

Col Michael A Dunn
Office of Assistant Secretary of Defense Health Affairs

Christine Durbak
World Information Transfer

Robert Eagelman
Population Action International

Anthony S Earl
Center for Clean Air Policy

William E Easterling
University of Nebraska

Sylvia Edgerton
U S Department of Energy

James A Edmonds
Pacific Northwest Laboratory

Laura Efros
Office of Science and Technology Policy

Gary B Ellis
National Institutes of Health

Tom Eng
U S Senate

Paul R Epstein
Harvard University Medical School

Dawn Erlandson
Friends of the Earth

Christine Ervin
U S Department of Energy

Elaine C Esber
Food and Drug Administration

Ruth A Etzel
Centers for Disease Control and Prevention

Gary R Evans
U S Department of Agriculture

William H Farland
Environmental Protection Agency

Kevin Fay
International Climate Change Partnership

Warren Ferster
Space News

Ralph Ted Field
National Association of Physicians for the Environment

George Fisher
John Hopkins University

Lora E Fleming
University of Miami

Dana A Focks
U S Department of Agriculture

Loren B Ford
Environmental Protection Agency

Michael Fosberg
U S Department of Agriculture, Forest Service

Marvin Frazier
U S Department of Energy

Kenneth Frederick
Resources for the Future

Clifford J Gabriel
American Institute of Biological Sciences

Ashok Gadgil
Lawrence Berkeley National Laboratory

Steven K Galson
Environmental Protection Agency

Mary M Gant
National Institute of Environmental Health Sciences

David Gardiner
Environmental Protection Agency

Bronson Gardner
Global Climate Coalition

Martha Geores
University of Maryland

Brigitta Gerwen
Netherlands National Institute of Public Health

Herman Gibb
Environmental Protection Agency

John H Gibbons
The White House

Lewis E Gilbert
Columbia University

William H Glaze
University of North Carolina

Patricia Glick
Sierra Club

Lynn R Goldman
Environmental Protection Agency

Bernard D Goldstein
University of Medicine and Dentistry of New Jersey and Robert Wood Johnson Medical School

Robert Gordon
Institute of International Education

Anne Grambsch
Environmental Protection Agency

Erick Gray
Universal Healthwatch, Inc

Robert H Gray
University of Michigan

Gina C Green
The Nature Conservancy

Harry L Greene II
Massachusetts Medical Society

Nancy Greenspan
Environmental Network

Priscilla C Grew
University of Nebraska, Lincoln

Francesca T Grifo
Center for Biodiversity and Conservation Museum of Natural History

John T Grupenhoff
National Association of Physicians for the Environment

Duane J Gubler
Centers for Disease Control and Prevention

Audrey Haar
Coal and Synfuels Technology

Craig Haas
Environmental Protection Agency

Demisse Habte
Center for Health and Population Research

Andrew Haines
University College of Middlesex

Scott A Hajost
International Union for Conservation of Nature and Natural Resources-U S

Davie Hales
Agency for International Development

J Michael Hall
National Oceanic and Atmospheric Administration

Scott B Halstead
U S Navy

Todd Halvorsen
National Institute of Environmental Health Sciences

Mark Hammond
British Embassy

Mark Handel
National Research Council

Deborah Hanfman
Office of Science and Technology Policy

William R Harlan
National Institutes of Health

Lowell T Harmison
Gallary House

James A Harrell
Public Health Service

Robert Harris
National Aeronautics and Space Administration

Polly Harrison
Institute of Medicine

John K Hartsock
University of Maryland

Peter I Hartsock
National Institute on Drug Abuse

Joseph Huang
Scientist

Abraham Haspel
U S Department of Energy

Cheryl A Hayden
American Academy of Dermatology

Raymond Hayes
Howard University College of Medicine

Karen Hein
Institute of Medicine

Merrill Heit
U S Department of Energy

Roger C Herdman
Office of Technology Assessment, U S Congress

Beth Hileman
Chemical and Engineering News

Eric Holdsworth
Global Climate Coalition

Rachel M Hopp
Hopp and Associates

William H Hooke
National Oceanic and Atmospheric Administration

Sarah Horrigan
Office of Management and Budget

Thomas Hourigan
U S Agency for International Development

Sharon Hrynkow
National Institutes of Health

Drusilla Hufford
Environmental Protection Agency

Jeffrey A Hunker
U S Department of Commerce

S Taseer Hussain
Howard University

Craig Hyams
Naval Medical Research Institute

Noreen A Hynes
Peace Corps

Donald J Igo
U S Department of Transportation

Carrie Ingalls
Institute of Medicine

Richard J Jackson
Centers for Disease Control and Prevention

Paul F Jamason
University of Delaware

Christer T Jansen
University of Turku, Finland

Nyka Jasper
U S Agency for International Development

Jim Jensen
U S Agency for International Development

James Jessleman
Academy for Educational Development

Stephen C Joseph
U S Department of Defense

John R Justus
Library of Congress

Peter R Jutro
Environmental Protection Agency

Laurence S Kalkstein
University of Delaware

Carla Kappell
Agency for International Development

John Kallos
Columbia Business School

Timothy P Kanaley
Institute of Medicine

Sally Kane
Council of Economic Advisers

Thomas R Karl
National Climatic Data Center

Eileen Kennedy
Center for Nutrition Policy and Promotion

Charles Kennel
National Aeronautic and Space Administration

John L Kermond
National Oceanic and Atmospheric Association

Katherine Kirkland
Association of Occupational and Environmental Clinics

Thomas M Kirlin
American Petroleum Institute

Heidi M Klein
National Association of City and County Health Officials

Edward Knipling
U S Department of Agriculture

Andrei P Kozlov
National Institutes of Health

Tim R Kramer
U S Department of Agriculture

Kalee Kreider
Ozone Action

Katharine Kripke
Stanford University

Margaret Kripke
M D Anderson Cancer Center

Jon Kusler
Association of Wetland Manager

Sandra L LaFevre
Reinsurance Association of America

Carol Lancaster
Agency for International Development

Stephen Landry
Agency for International Development

Hiram Larew
Agency for International Development

Daniel Lashof
Natural Research Defense Council

Sharon LeDuc
Environmental Protection Agency

Alexander Leaf
Harvard University Medical School

Joel M Levy
National Oceanic and Atmospheric Administration

Elizabet Lindgren
Natural Resources
Management Institute
Stockholm University

Andrew Lewis
U S Department of State

Steven A Lloyd
Johns Hopkins University

Ken Locklin
A T International

David C Logan
Mobile Oil Corporation

Janice Longstreth
Waste Policy Institute

Ronald D Lorton
U S Department of State,
Bureau of Oceans and
International Environmental
and Scientific Affairs

Thomas E Lovejoy
Smithsonian Institution

Max Lum
National Institute for Occupational Safety and Health

William H Lyerly, Jr
Agency for International
Development

Diana MacArthur
Dynamac Corporation

Michael C MacCracken
U S Global Change
Research Program

Thomas F Malone
The Sigma Xi Scientific
Research Society

Adam Markham
World Wildlife Federation

Joyce M Martin
Environmental Protection
Agency

W J Martens
University of Limberg,
Netherlands

DaCosta Mason
American Association of
Retired Persons

Donald R Mattison
University of Pittsburgh

Lisa May
Aurora Flight Sciences

Nancy Maynard
National Aeronautic and
Space Administration

Michael McCally
Mt Sinai Medical Center

Catherine E McDermott
Grantmakers in Health

Alan McDonald
American Academy of Arts
and Sciences

Al McGartland
Environmental Protection
Agency

Anthony McMichael
Department of Epidemiology
and Population

Gary McNeil
Council for Environmental
Quality

L H Meredith
U S Global Change
Research Program

Kathleen Michels
Agency for International
Development

Alan Miller
Center for Global Change

Alvin J Miller
National Oceanic and
Atmospheric Association

Irving Mintzer
Center for Global Change

Curtis Moore
Curtis Moore Associates

Roscoe M Moore, Jr
Office of International Health

Jennifer Morgan
Climate Action Network

Wayne A Morissey
Library of Congress

Robert T Morris
Medical College of Wisconsin

Steven Morse
Rockefeller University

Harry Moses
U S Department of Energy

Richard Moss
Intergovernmental Panel on Climate Change

Jeryl L Mumpower
Rockefeller College

Robert K Musil
Physicians for Social Responsibility

Charles E Myers
National Science Foundation

Carolyn Needleman
Bryn Mawr College

Elvia E Neibla
U S Department of Agriculture, Forest Service

Henry Newhouse
National Oceanic and Atmospheric Administration

Sheila A Newton
U S Department of Health and Human Services

Claudia Nierenberg
National Oceanic and Atmospheric Administration

Frances P Noonan
George Washington University School of Medicine

Michael Northrop
Rockefeller Brothers Fund

Susan Norwood
U S Department of Energy

Edward W Novak
Army Environmental Policy Institute

Christine O'Brien
Environmental Protection Agency

James J O'Brien
Florida State University

Robert O'Keefe
Health Effects Institute

Tara O'Toole
U S Department of Energy

Ellen Odgen
Agency for International Development

David Oot
Agency for International Development

Michael Oppenheimer
Environmental Defense Fund

Brett Orlando
Office of Science and Technology Policy

Joseph V Osterman
Defense Research and Acquisition

Horst Otterstetter
Pan American Health Organization

Countess Alicia Paolozzi
National Association of Physicians for the Environment

John Passacantanoo
Ozone Action

Ari Patrinos
U S Department of Energy

Jonathan A Patz
Johns Hopkins School of Public Health

David Pelletier
Cornell University

Michele Pena
Climate Institute

John S Perry
National Academy of Sciences

Jonathan Pershing
U S Department of State

Anne C Petersen
National Science Foundation

Karen Peterson
National Institutes of Health

Annie Petsonk
Environmental Defense Fund

Paul B Phelps
Science Writer

Winfred M Phillips
University of Florida

Rick Piltz
U S Global Change Research Program

Warren T Piver
National Institute of Environmental Health Sciences

Rafe Pomerance
U S Department of State

Andrew Pope
Institute of Medicine

Jessica Poppele
The World Bank

Glenn Prickett
Agency for International Development

Ronald H Pulliam
National Biological Service

Ata Qureshi
Climate Institute

David P Rall
Institute of Medicine

Jason Randall
Office of Science and Technology Policy

Stephen Rattien
National Research Council

Susan V Raymond
New York Academy of Sciences

Leslie A Real
Indiana University

Debbie Reed
U S Department of Agriculture, Office of the Secretary

Mickey Reed
Cannon House Office Building

Walter V Reid
World Resources Institute

John Reilly
U S Department of Agriculture

David Rejeski
Office of Science and Technology Policy

Robert Repetto
World Resources Institute

Donald L Rheem
E Bruce Harrison Company

Richard Richels
Electric Power Research Institute

Courtney Riordan
Environmental Protection Agency

Michael Rodemeyer
U S House of Representatives

Julie Roque
Office of Science and Technology Policy

Norman J Rosenberg
Battelle-Pacific Northwest Laboratories

Arthur Rosenfeld
U S Department of Energy

Herbert S Rosenkranz
University of Pittsburgh

Joshua Rosenthal
Fogarty International Center

Reva Rubenstein
Environmental Protection Agency

Philip R Russell
Johns Hopkins University

Alfred J Saah
Johns Hopkins University

Marla Salmon
U S Department of Health and Human Services

Joel Saltz
University of Maryland

Haleh V Samiei
Association for Women in Science

Kim Sanzo
Center for International Environmental Law

Joel D Scheraga
Environmental Protection Agency

Ellen Schmidt
Greenpeace International

Gabriel Schmunis
Pan-American Health Organization/World Health Organization

Joe Schwartz
Physicians for Social Responsibility

Joel Schwartz
Harvard University School of Public Health

John Kimball Scott
National Association of Physicians for the Environment

Louise Scott
Consultant

Glenn E Schweitzer
National Research Council

Jeff Seabright
Agency for International Development

Stephen Seidel
Council on Environmental Quality

Loren W Setlow
National Research Council

Valerie P Setlow
Institute of Medicine

Moira Shannon
U S Department of Health and Human Services

Dave Sharma
U S Department of Transportation

Eileen L Shea
Institute of Global Environmental Society

Artie Shelton
U S Department of Veterans Affairs

Clive Shiff
Johns Hopkins University

Martha Shimkin
Pan American Health Organization

Kenneth I Shine
Institute of Medicine

John Shlaes
Global Climate Coalition

Robert Shope
University of Texas

Michael Simpson
Library of Congress

Holly Sims
State University of New York

James B Sitrick
Agency for International Development

Rudi Slooff
World Health Organization

Meta Snyder
Registered Nurse

Anthony Socci
U S Global Change Research Program

Rosemary Sokas
George Washington University

Anne K Solomon
U S Department of State

William Sprigg
National Academy of Sciences

Ray Squitieri
U S Treasury

William Sprigg
National Academy of Sciences

Jennifer Steinberg
Journal of NIH Research

Macol Stewart
National Oceanic and Atmospheric Administration

Paul Stolpman
Environmental Protection Agency

Richard E Stuckey
Center for Application of Sciences and Technology

Nicholas Sundt
Global Change

Mark Sutton
U S Global Climate Change Research Program

Fred Swader
U S Department of Agriculture

Lisa Swann
Environmental Defense Fund

William H Swartz
Johns Hopkins University

Guanri Tan
University of Delaware

Paulo Fernando Teixeira
Pan American Health Organization

David Thomassen
U S Department of Energy

Margo Thorning
American Council for Capital Formation

David Tejadd-De-Rivero
Pan American Health Organization

Tim Tinker
Agency for Toxic Substances and Disease Registry

Steen Tinning
Fredericksberg Hospital

Maria Livia Tosato
Embassy of Italy

Dennis W Trent
Food and Drug Administration, Center for Biologics Evaluation and Research

Robert J Tuccillo
Office of Management and Budget

Waimar Tun
Center for Health and Population Research

David Unnewehr
American Insurance Association

Rosario Val
Pan-American Health Organization

Bob Vallario
U S Department of Energy

Ann Van Dusen
Agency for International Development

Basil Vareldzis
Agency for International Development

David Verbel
Biometrics Research Institute

Romana Vysatova
Domestic Policy Council

Robert B Wainwright
Centers for Disease Control and Prevention

Jane Wales
Office of Science and Technology Policy

Tom Waltz
World Bank

Tracy M Walton, Jr
National Medical Association

Bud Ward
National Safety Council

Kathryn Washburn
U S Department of the Interior

Elizabeth Festa Watson
Chemical Manufacturers Association

Jeffrey Watson
Royal Society of Canada

Robert T Watson
Office of Science and Technology Policy

Peyton Weary
University of Virginia Hospital

Randall Wentsel
U S Army

Carol Werner
Environmental and Energy Study Institute

William E Westermeyer
National Research Council

William White
Environmental Protection Agency

Carol E Whitman
U S Department of Agriculture

Natalie Williams
University of Delaware

Mark L Wilson
Yale University School of Medicine

Mary E Wilson
Harvard University

Nancy C Wilson
Climate Institute

Tom Wilson
Electric Power Research Institute

Robert Wolcott
Environmental Protection Agency

M Gordon Wolman
Johns Hopkins University

Byron L Wood
National Aeronautics and Space Administration Ames Research Center

Robert C Worrest
Consortium for Earth Science Information Network

Stephen W Wyatt
Centers for Disease Control and Prevention

Tammy R Wyles
Georgia-Pacific Corporation

Ann G Wylie
University of Maryland

Roger E Wyse
University of Wisconsin-Madison

Timothy Yarling
Japan International Cooperation Agency

Terry F Yosie
Environmental Development Group

Elizabeth Younger
Younger and Rata

Eve Carroll Zentrick
Uniformed Services University

Brigitta Zuidema-van Gerwen
Netherlands National Institute of Public Health and Environmental Protection

APPENDIX D

Abstracts of Conference Presentations

GEORGE ALLEYNE, M D

The reemergence in the Americas of infectious disease that had been controlled in the past, such as cholera, plague, and dengue, as well as the emergence of new infectious agents, such as Hanta and Guanarito viruses, E coli 0 157, and cryptosporidia, have had a direct impact on health policy and the prevention of disease Over the past several years, governmental and nongovernmental organizations have been working closely to modify health policy in order to place more emphasis on disease prevention A major concern is the changing dynamics of disease transmission, which is influenced by migration, land use, and environmental degradation Many lines of action are being perused to prevent infectious diseases One requirement is flexible management within the health sector, which is close to the population and that can adapt to the changing patterns of disease In addition, the wide impact of infectious diseases, such as AIDS, mandates a policy of increased intersectorial cooperation There must be fluid communication and management of health problems among the sectors of health, environment, and agriculture, supported by competent research based on policy analysis It is believed that policy reform, combined with broad public support gained by effective use of the mass media, will allow us to confront the health problems caused by climate change and environmental degradation

J BRIAN ATWOOD

Climate change is believed to cause a wide variety of deleterious effects, including desertification, change in agricultural patterns, and disease The effect is both direct and indirect, the causes may be either natural or manmade To the extent that climate change and its impacts are influenced by human activity, methods must be found to mitigate, adapt, or respond The U S government is obligated to exercise leadership at home and abroad to ensure that responses are appropriate and timely

Who is at risk? Every human being is vulnerable but the citizens of developing countries and regions face the most immediate dangers In those nations, climatic change and the necessary responses may be greatest, but available resources are most limited Clearly, the preventive and responsive measures we employ to deal with climate change and its effects must involve every affected person and operate society-wide

ERIC CHIVIAN, M D

Despite increasing evidence that climate change and ozone depletion may have disastrous consequences for human health, there is little understanding, either among policy-makers or the public, of the extent of the possible threat to human life Physicians and public health professionals should be central figures in helping to promote this understanding, but they are by and large uniformed, as their education does not in general cover the relationship of global environmental change to human health This presentation shall look at the role of the medical and public health communities in global environmental issues, such as climate change and ozone depletion, and shall address the growing need for their education and involvement

RITA R COLWELL, Ph D

The origin and cyclical nature of cholera has intrigued scientists and public health officials Robert Koch postulated environmental origins of cholera, but proof was not established until the tools of molecular biology and immunology were available Work on environmental aspects of cholera during the past 20 years has revealed an association of *Vibrio cholerae* with zooplankton and marine and estuarine systems Furthermore, the capability of *V cholerae* to enter a dormant, that is, viable but nonculturable state, has offered an explanation for the inability to isolate it between epidemics With fluorescent monoclonal antibody and gene probes, coupled with PCR amplification, it has been possible to detect and monitor *V cholerae* in the environment Furthermore, it has been shown that plankton blooms are correlated with increased incidence of *V cholerae* Studies carried out in Bangladesh provided the link between cholera outbreaks and plankton populations Studies in progress, employing satellite imagery, will permit retrospective and prospective analyses of marine plankton and the cholera outbreak in Latin America during 1991–1992 The El Niño event appears to be closely associated with this cholera outbreak Perturbations of the marine ecosystem may be the key to the eratic, cyclical nature of cholera epidemics

STEPHEN C JOSEPH, M D , M P H

Global surveillance is critical to national security and plays a vital role in the mission of the Department of Defense (DoD) Military forces can be deployed to virtually any area of the world on short notice, knowledge of emerging diseases and their potential impact on military operations greatly assist us in preparing countermeasures to avoid such threats, reduce their impact, and provide a rapid response to outbreaks At present, three things need to be accomplished First, DoD—using existing resources—will establish a surveillance and response capability in its overseas laboratories Second, along with other U S government agencies, DoD will link international and host-nation training of field epidemiologists and researchers to existing DoD laboratories, creating regional networks Third, U S government agencies in international partnerships need to establish a functional surveillance system on the Internet, of which PROMED is an excellent early prototype

LAURENCE KALKSTEIN, Ph D

Direct weather impacts, such as heat waves, have a profound effect upon human health, during unusually hot conditions, deaths from all causes can rise over 50 percent above average levels The elderly, poor, and very young appear disproportionately stressed The impact of climate change could exacerbate the situation, as more extreme hot weather, and a greater frequency of oppressive air masses could cause the number of heat-related deaths to rise significantly Although developing nations could suffer inordinately, it is quite obvious that extreme heat can cause havoc in American cities, as evidenced by the recent Chicago heat wave

There are a number of unanswered or disputed questions involving the impact of climate change on mortality and morbidity Will increasing winter warmth compensate somewhat for hotter summers by decreasing winter mortality? What will be the impact of increasing accessibility to air conditioning? Would many of the people who die of excess heat represent deaths that would have occurred shortly afterward, regardless of the weather? What is the acclimatization potential of the population if future temperatures rise? Can excessive deaths be mitigated with the development of watch/warning systems that provide the appropriate agencies with advance notice about impending dangerous weather conditions? Finally, how does the combination of hot weather and air pollution contribute to increasing human mortality, and what are the implications of a global warming on weather or pollution impacts?

MARGARET L KRIPKE, Ph D

The amount of ultraviolet-B (UV-B) radiation in natural sunlight is dependent on the concentration of ozone in the atmosphere A reduction in ozone will increase the amount of UV-B radiation reaching the earth's surface Even a small increase in UV-B radiation is likely to have important consequences for human health Although a small amount of UV-B is necessary for production of vitamin D, excessive exposure causes squamous and basal cell skin cancers and contributes to the incidence of melanoma skin cancer Ocular changes that lead to certain types of cataract are also a consequence of excessive exposure to UV-B radiation UV-B radiation can also interfere with the body's immune system, this constitutes one of the most potentially dangerous effects of UV-B because of the possibility that immunity to infectious diseases may be compromised Unfortunately, too little is know about the immunology consequences of UV-B radiation to make predictions about the impact of ozone depletion on human diseases

ANTHONY J McMICHAEL, M D , Ph D

Three things about this topic need emphasis scale, context, and uncertainty First, the anticipated health risks are not of a localized kind, they are of large scale, impinging at population level, and transcending national boundaries Second, the risks are not just "more of the same" (more heatwaves, air pollution, etc) Rather, they would arise substantially via indirect pathways (by disturbance of natural systems, e g , the ecology of infective agents, food production, and freshwater supplies) Third, forecasting them entails complexity, uncertainty, and a long time horizon It is tempting to focus on the more familiar risks, increased deaths from heatwaves (especially in the very young, frail, and elderly), trauma from floods and storms, and—from stratospheric ozone depletion—more cases of skin cancer However, in the long term, sustained changes in climate and in climate-dependent natural systems (particularly if also subjected to other environmental or ecological stresses) would result in (a) altered patterns of infectious diseases, especially vector-borne diseases (malaria, dengue, etc), (b) some regional declines in food production, and (c) population displacement (rising seas, declining agriculture, food shortages, and weather disasters) and its many public health consequences Combinations of mobile infections, malnutrition, and social stress—especially in displaced and migrating groups—could amplify the health impacts of climate change

STEPHEN S MORSE, Ph D

"Emerging infectious diseases" are those that are newly appeared in the population or are rapidly increasing their incidence or geographic range (e g , HIV/AIDS, cholera in South America and Africa, Ebola in Africa, and Hantavirus pulmonary syndrome and Lyme disease in the United States) Most emerging infections are caused by pathogens that are present in the environment but are newly introduced into humans, often from another species as a result of changing ecological or environmental conditions that increase the chance of human contact, or are infections that were once geographically isolated but now have an opportunity to reach larger human populations Climate may often be a factor For example, with Hantavirus pulmonary syndrome in the southwestern United States in 1993, the virus probably was long present in local rodent populations, but unusual local weather conditions led to an exceptionally large rodent population, with greater opportunities for people to come in contact with infected rodents (and, hence, with the virus), the weather anomaly itself may have been due to large-scale climatic effects Human population movements, which can introduce remote infections to a large population, also are often a factor in the emergence of disease The mass movement of workers from rural areas to cities, largely driven by economic conditions, can allow a previously isolated infection to reach larger numbers of people (this probably happened with HIV) Climate changes, by potentially decreasing productivity of local rural agriculture, could accelerate this migration As a final example, epidemiologists have long documented a close relationship between climatic conditions and epidemics of childhood bacterial meningitis (which can also spread globally by travel) in parts of Africa where the disease naturally occurs

JOEL SCHWARTZ, Ph D

Increases in temperature in the Northern Hemisphere will result in increased demand for air conditioning, and hence increased emissions from electric power generation, which are the major source of fine particles in much of North America Increased temperature will also lead to increased ozone formation While the degree of pollution resulting from climate change is relatively unclear, the effects of particulate air pollution and ozone are becoming increasingly clear Increased particulate air pollution is associated with increased risk of mortality, decreased life expectancy, and increased hospital admissions for heart and respiratory illness Ozone is associated with increased hospital admissions for respiratory illness The magnitude of these risks can now be quantified

ROBERT E SHOPE, M D

Some probable effects of global warming are (a) an increase in temperatures especially at night, (b) greater warming in polar than in tropical latitudes, (c) an increase in the frequency of tropical storms, (d) loss of forests, and (e) migration of humans and their domestic animals north in the Northern Hemisphere These changes will affect the health of people and animals, especially through increased numbers and efficiency of arthropod and rodent vectors of disease

Vector-borne diseases such as dengue, St Louis encephalitis, Lyme disease, yellow fever, malaria, and Rift Valley fever, as well as bat rabies and Hantaviruses, will be affected These diseases have in common an ecological component such that climate limits their distribution Most occur in tropical areas and have either a mosquito, tick, or wild animal as part of their cycle In many cases the infectious agent multiplies better in the reservoir at high ambient temperature, and often the vector depends on ample rainfall to thrive

In the case of Lyme disease, climate influences both the infectious agent and the hosts that maintain the life-cycle of the vector Dengue is a tropical virus disease transmitted by *Aedes* mosquitoes This disease, with warming, appears to be moving northward to the U S -Mexican border

ROBERT T WATSON, Ph D

The Earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere The buildup of greenhouse gases—primarily carbon dioxide, methane, nitrous oxide and chlorofluorocarbons (CFCs)—is changing the radiation balance of the planet The basic heat-trapping property of these greenhouse gases is essentially undisputed However, there is considerable scientific uncertainty about exactly how and when the Earth's climate will respond to enhanced greenhouse gases The direct effects of climate change will include changes in temperature, precipitation, soil moisture, and sea level Such changes could have adverse effects on ecological systems, human health, and socioeconomic sectors

Accumulation of CFCs in the upper atmosphere has already led to world-wide depletion of the ozone layer and an ozone hole in springtime over Antarctica Ozone filters out harmful ultraviolet radiation and keeps it from reaching the Earth's surface Recent international agreements to phase out CFCs are beginning to show results, we now expect peak depletion to occur about the turn of the century, and the ozone layer should recover over the next several decades

Ozone depletion and climate change are complex problems that will affect the economy and the quality of life for this and future generations The lag time between emission of the gases and their impact is on the order of decades to centuries, so, too, is the time needed to reverse any effects Thus, decisions in the near term will have long-term consequences

M GORDON "REDS" WOLMAN, Ph D

The geologic record provides clear evidence of climatically induced changes in the quantity and quality of fresh water on the globe Major fluctuations in climate, in the last 10,000 years and before, have resulted in the creation and demise of lakes and river systems Temperature perturbations of only a few degrees have also been accompanied by significant increases in the frequency of floods, and similar flood events are associated with El Niño oscillations in some regions Increasing seasonal runoff at some locations in the United States may be associated with a warming trend during this century, but the record is not consistent Climate change influences water quality directly and indirectly, directly through changes in water temperature and associated chemical and biochemical phenomena (e g , dissolved oxygen, algae), and indirectly through alterations of vegetation and the erosional process on land Sediment yield and accompanying organic and inorganic constituents may alter the quality of ambient flow and the characteristics of the habitat Human impacts acting on both landscape and climate are often inseparable from the variable behavior of natural processes

DAVID OOT, Ph D

More than 800 million people, or 15 percent of the world's total population, are food insecure They lack the economic and physical access to adequate food to meet their dietary needs and to lead healthy and productive lives Inadequate food consumption is a primary cause of malnutrition along with infection and poor health For 1993, the UN reports that over 34 percent of all preschool children in developing countries are malnourished From recent research we know that protein energy malnutrition (PEM), even in its mild-to-moderate forms, contributes to 56 percent of child deaths in 53 developing countries The terrible burden of PEM on child survival is even greater when the toll of hidden hunger due to micronutrient deficiencies—especially of Vitamin A, which leads to blindness, of iron, causing anemia, and of iodine deficiency, which leads to impaired mental performance

Projections through 2020 suggest an increasing number of malnourished people, especially in South Asia Estimates for the numbers of additional people at risk of hunger range from a conservative 100 million to around 360 million by the year 2060 Cereal prices were estimated to increase dramatically from 25 to 125 percent, with profound implications for the net purchasers of food, the poor The differential and negative impact in the developing world has implications for the range and types of actions that need to be taken to address the health and nutrition consequences

— Early warning and famine mitigation,

— Institutional strengthening in developing countries to predict and respond to environmental and related emergencies,

— Development assistance to vulnerable countries for promoting and refining adaptive measures to improve food production and income generation,

— Increased emphasis on basic health and nutrition services including family planning,

— Focused and coherent approaches to effective utilization of U S food resources targeted to the vulnerable, and

— Global action and leadership to advance scientific knowledge and its application

ADDITIONAL ABSTRACT OF CONFERENCE PRESENTATIONS

J Michael Hall, Ph D , and Paul Epstein, M D , M P H

During the past 15 years scientists have made dramatic progress in predicting the El Niño-Southern Oscillation (ENSO) phenomenon and related seasonal to interannual climate variability in many critical areas of the globe, particularly in the tropics and subtropics, where the ENSO signal and impacts are strongest Current ENSO-forecasting capabilities can predict climate trends for many affected regions of the world with a lead time of up to 1 year Accurate and timely forecasts allow policy-makers to mitigate the potentially devastating economic impacts of ENSO by adapting planning processes to short-term climate fluctuations The ability to anticipate an upcoming anomalous wet or dry period is already being used by decision-makers in several tropical countries Past successes in climate forecasting and impacts modeling in the agriculture and hydrology sectors have set the stage for a new line of investigation and application in the health sector

El Niño events—producing warmer and wetter years periodically in regions around the world—may be associated with upsurges of cholera and other water-borne diseases, new appearances of harmful algal blooms, disease events across taxa in the marine environment, outbreaks of malaria and dengue fever, and the abundance of rodents as pests and pathogen vectors Multidisciplinary application centers integrating climate forecasting with ecological and social information can provide early warning for multiple sectors including hydroelectric energy, water resources management, and agriculture (“Famine Early Warning Systems”) With additional investigation, the potential exists to extend these application efforts to human health (“Health Early Warning Systems”) While climate circumscribes the distribution of many disease vectors, extreme events may determine the timing of outbreaks

In considering El Niño as an analogue for long-term climate change, lessons can be learned from El Niño’s effects on extreme events changes in droughts, floods, and minimum and maximum temperatures Study of the linkage between ENSO and health is beginning to reveal important threshold effects and provide tools for predicting the impacts of global climate change that can be tested and perfected on verifiable timescales The significance of ENSO may be greater still, as some scientists believe that global climate change may be experienced in large part through changes in climatic extremes and climate variability For some diseases, changes in climatic extremes may be even more important than changes in average temperature and average precipitation