- Tropical geography, poor water and food security, low socioeconomic status and political instability define the regions that would be most vulnerable to the health effects of climate change.

- The interactions between the environment (including climate and weather) and the vector/pathogen/host system are extremely complex. It is important to avoid simplistic interpretations when discussing interventions aimed at reducing vector-borne (VBD) and water-borne (WBD) diseases.

- Attempts to delineate the health effects of global climate change are hampered by a paucity of information about disease identification, ecological and environmental factors, and local weather conditions.

- Models are often quoted as the shape of things to come. Current VBD models cannot predict the impact of climate change on disease transmission several years in the future with any accuracy.

- The number of laboratories doing disease surveillance on emerging and re-emerging infectious diseases is relatively small, and in many places they are very poorly funded. Improved surveillance could save lives.

The Annapolis Center is a national non-profit organization that supports and promotes responsible environmental, health, and safety decision-making. The Center seeks to improve public debate about potential risks from hazards and to ensure that regulatory responses, if necessary, are appropriate to the risks.

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Workshop on Global Climate Change and Human Health

The Annapolis Center

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Workshop on Global Climate Change and Human Health

The climate of the earth has never been static. It exists in a continuous state of change, with numerous short-term fluctuations superimposed on the major changes we know as ice ages and their subsequent periods of warming. For the last several hundred years, the earth's climate has been gradually warming. While there is considerable debate about why the earth's climate changes, some scientists believe that there is evidence to suggest that the accumulation of CO2 produced by burning fossil fuels may be contributing to the present warming trend.

However, The Annapolis Center's Workshop on Global Climate Change and Human Health did not attempt to answer the questions "is global climate change occurring", or "how much influence is man having on the earth's climate", or "if global warming is occurring, how fast will the change occur"? These questions were addressed in an earlier workshop held by the Center titled: "Global Climate Change: Policy Making in the Context of Scientific and Economic Uncertainty" (October 1997).

Assuming that the warming trend that has been underway for approximately the last five hundred years will continue during the coming century, The Annapolis Center's Workshop on Global Climate Change and Human Health focused on those factors that might impact human health during that time. Also examined were the steps that might be taken proactively to mitigate the effects of continued global warming on human health. This workshop did not consider the consequences of global cooling, a possibility being increasingly discussed as a potential consequence of current warming in the North Atlantic.

In discussions about the potential health effects of continued global warming, the focus quickly turned to vector-borne diseases (VBD) and water borne diseases (WBD). However, several workshop participants held that the greatest health impacts of climate change will occur as a result of changes in global rainfall patterns. This could result in a reduced capacity to meet basic human needs of food, water, fuel, and shelter. The combination of decreased access to fresh water, severe weather events, decreased agricultural production, and environmental migration could have effects several orders of magnitude greater than local changes in vector-borne diseases and water-borne diseases. Other participants argued that a warmer climate could increase global rainfall and improve global agricultural productivity. While recognizing the potential for major health impacts from these effects, the discussion focused particularly on those caused by VBD and WBD.

The participants agreed that populations with the fewest resources would be the most vulnerable to the adverse health effects of climate change.

The following points emerged in the discussion:

- Climate change is only one of a multitude of factors that are likely to have significant influence on human health over the coming Century.

- Some indication of the possible effects of climate change can be gained from the impact of short-term climatic variation - weather - on human health.

- Tropical geography, poor water and food security, low socioeconomic status and political instability define the regions that would be most vulnerable to the health effects of climate change.

- The interactions between the environment (including climate and weather) and the vector/pathogen/host system are extremely complex. It is important to avoid simplistic interpretations when discussing interventions aimed at reducing vector-borne (VBD) and water-borne (WBD) diseases.

Climate is the long-term summation of weather events. When we discuss weather, we are talking about days, months, or years. When we discuss climate, we are talking about decades and centuries.

- Attempts to delineate the health effects of global climate change are hampered by a paucity of information about disease identification, ecological and environmental factors, and local weather conditions.

- Attempts to define the health effects of global climate change are hampered by a paucity of information about disease dynamics and ecology and the impacts on these of environmental factors, including climate and weather.

- Models are often quoted as the shape of things to come. Current VBD models cannot predict the impact of climate change on disease transmission several years in the future with any accuracy. The development of varying scenario-based models could provide an understanding of the range of possibilities in the future.

- Steps that could be taken in the next decades to reduce the prevalence of VBD or WBD are listed.

Factors Significant to Human Health

What major factors are anticipated to have a significant influence on human health over the next 100 years?

Population growth and density, demographic changes and urbanization

Mobility of humans, vectors, and pathogens e.g., pathogens interact and evolve, spread to new geographic areas, and adapt to new ecosystems

Emergence of new and re-emergence of old diseases, i.e. drug resistant TB, etc., parasitic diseases, and lung problems now showing up in prehistoric mummies, perhaps even the re-emergence of smallpox, etc.

Increasing drug resistance and new drugs, vaccines and pesticides.

Economics, energy and food supply, sanitation, public health infrastructure and potable water availability

War and/or genocide

Human behavior, e.g. AIDS, encroachment on flood plains, junk food and tobacco use, especially in emerging nations

Weather and climate variations, e.g. floods, hurricanes, heat extremes

Politics, e.g., food shortages, health care delivery, research

The emergence of new diseases (e.g., HIV, Ebola, Hantavirus etc.)

Climate, Weather and Human Health

What aspects of weather will have the greatest effect?

Climate change in the past has been gradual. If climate change is gradual, responses by disease-carrying vectors and their pathogens may be better anticipated, allowing for preventive health measures to be implemented. However, if the predictions of some scientists are correct that global warming is occurring at an extraordinarily rapid rate on a geological time scale, even on a biological time scale, the rate of change may be so rapid that warming could be accompanied by large variance in weather . . . greater extremes of weather over short time periods. If this occurs it will be more difficult to predict how vectors and parasites may respond, as well as to determine the capacity for humans to adapt to such changes. El Niño and similar phenomena provide an opportunity to observe the impact of such changes in the short-term.

As an example: geographic information and remote sensing have been applied to data gathered during the Hantavirus outbreak that followed the '91-'92 El Niño and used to model the geographic distribution of disease (i.e., to predict the areas where conditions are most likely to produce outbreaks.) This model helped alert the Centers for Disease Control & Prevention and the Indian Health Service that another outbreak was possible in the summer of 1998.

How will global climate changes affect health?

In an area endemic for vector-borne diseases, local rainfall, temperature, and humidity impact directly on disease transmission, and can be very different from overall global temperature or precipitation changes.

Present global climate models are greatly limited by problems of spatial resolution. Thus, the prediction of local weather conditions -- key to determining infectious disease transmission -- will continue to present a major obstacle to predictions of disease prevalence. The testing of new tools in downscaled global models is therefore a priority.

We cannot forecast degrees of climate change, nor the effects of such change (heating or cooling) on human health. However, in the event that the present warming trend continues, maintenance and improvement of public health resources and effective disease monitoring are central to our ability to adapt to potential change.

Regions at Risk

Where will climatic changes be felt most intensely?

People and nations with the fewest resources, both natural and economic, will be least able to adapt to climate change. Populations at particular risk should be identified so that they can be helped to manage their resources and take necessary steps to decrease their vulnerability. Areas of poverty, especially with regard to availability of fresh water and arable land (food security) are already marginalized and may be particularly vulnerable to VBD and WBD. As socioeconomic conditions improve so do healthcare resources, thus decreasing the vulnerability of an area to VBD and WBD.

> How Weather Events Affect the Poor
>
> In 1998 Hurricane Mitch caused massive devastation in Central America with an estimated loss of over 9,000 lives. In comparison, the United States Midwest experienced massive spring flooding in 1998 with essentially no loss of life...
>
> An even better example may be Hurricane Georges, the intensity of which declined as it passed from Puerto Rico to the Dominican Republic. Although the total loss of life has not been established by the time of publication of this report, estimates vary from 250 to more than 1,200 in the Dominican Republic whereas in Puerto Rico the number was less than ten. Publicizing the weather forecast played a major role in averting the loss of life in Puerto Rico.

What defines the distribution of VBD and the likely effects on this of climate change?

The vulnerability of a region to the effects of climate change may be influenced by many factors. For vector-borne diseases (VBDs), latitude and altitude set broad limits on distributions. Higher latitudes generally have less VBD, although this was not always the case. For example, until relatively recently, malaria was endemic throughout much of Europe, extending nearly as far north as the Arctic Circle. During the 20th Century, improved sanitation and living conditions, as well as advances in medical care and vector control, have played a major role in restricting the disease to the tropics. Similarly, Dengue was once a major disease in much of the Southern United States, but today it is virtually absent. In 1922, there were an estimated 500,000 cases of Dengue in Texas alone, yet in the period from 1980 to 1996, only 46 autochthonous cases were confirmed in that State. By contrast, in the same period, in three smaller Mexican States that are contiguous with the Texas Border (Tamaulipas, Nuevo Leon, and Coahulia), 50,333 cases were reported during the same period. The climate in both regions is essentially identical, yet conditions for transmission are clearly different. Moreover, summers in the region are much hotter than in many tropical countries where Dengue is endemic. Clearly climate effects cannot be assessed in isolation from the many other important socioeconomic factors.

VBDs are not seen above certain altitudes. In many cases, the vector may be present, but transmission does not occur, mainly because the time taken for the pathogen to develop in the vector exceeds the survival rate (or lifetime) of the vector itself.

Complexity of Interactions for VBD and WBD

What factors influence the transmission of vector-borne and water-borne diseases?

There are many critical parameters that influence the transmission of pathogens. Of course, for a VBD, both the vector and pathogen must be present. For both VBD and WBD, weather-related variables -- temperature, rainfall, and humidity -- are important, as are socioeconomic and demographic variables, public health efforts, population density, and quality of shelter and food availability. The impacts of temperature and rainfall are multiple and depend on the vector itself, its habitat, and its interaction with people. The laboratory behavior of a vector is not necessarily a guide to its behavior. Understanding how weather interacts with a vector's biology may suggest that different types of control are needed. The nature and strain of the infectious agent, its mode of transmission, and the history of the disease in the population are also important.

What are the effects of temperature and rainfall on VBD?

The complex nature of environmental interactions can be appreciated by looking at the various effects of temperature. For the VBDs, the incubation period of the pathogen within the cold-blooded vector (known as the extrinsic incubation period, *i.e.*, the time from when the vector bites an infected person to the time when it is able to pass the pathogen to an uninfected person) is temperature dependent: The higher the temperature the shorter the extrinsic incubation period. Moreover, the rate of development of the vector itself will be enhanced by higher temperatures, but development may cease at extremely high or low temperatures. In addition, within a certain range, higher temperatures increase the speed of digestion of a bloodmeal, and therefore increase the frequency of feeding and the chances to spread an infection. Such an increase in feeding frequency can also shorten a vector's life span. Predators of vectors may also be more active in warmer weather, and also reduce the vector population. Thus the effects of temperature are complex, involving many systems, and may often appear counterintuitive. What is more, temperature can affect human behavior as well. If the temperature rises, people may move indoors to an air-conditioned environment (if accessible), thus decreasing contact with the vector. It is the temperature range of each effect and the interaction of all of them that will determine the final prevalence of a disease.

Mosquitoes, blackflies, and other vectors breed in water, so a change in rainfall patterns can change their breeding potential. However, the exact nature of the relationship is dependent on the biology and ecology of the species involved. Thus, for some species, an increase in rainfall may create the pools or fast-flowing rivers that serve as breeding sites; whereas for others, rainfall will flush their breeding sites and have a purging effect. By contrast, for some species, a decrease in rainfall may lead to storage of water, which creates artificial breeding sites that were not present in rainier periods. Humidity is often related to rainfall, and may influence the rate of evaporation of water in breeding sites, as well as the survival rate of adult vectors.

What is the status of vaccination for VBD?

Development of vaccines against tropical diseases of which the pathogen (particularly the human parasites) has shared a long evolution with man has been shown to be very complicated and effective vaccines have been developed against a number of viral diseases, such as yellow fever and Japanese encephalitis. For others, such as Dengue for which the seriousness of the disease is probably related to the complexities of the immune system, incomplete vaccination may even be dangerous. Existing vaccines need to be improved in terms of stability and ease of administration. For example, some current vaccines must be kept under refrigeration (a cold chain) until they are administered which makes transportation into remote regions of warm climates a problem. Delivery of vaccine to all those who could be helped by immunization is logistically difficult. In general, children and their mothers are more accessible to vaccination programs than the rest of the population.

Will aggressive vaccination programs be enough?

An added dimension to control VBD and WBD with vaccines is the continued presence of the infectious pathogen in a non-human reservoir population in nature. If immunity at any time wanes in the human population, the disease can readily reappear.

Improved Data Gathering

Accurate projections require sound data and analysis. Currently, disease surveillance and diagnosis, knowledge of ecology, environmental and infrastructure factors, and commitment to improved data gathering are not receiving sufficient resource support to provide this information. While remote-sensing data, available through NASA and NOAA have been useful, particularly in those regions of the Earth with less cloud cover, these data may not accurately reflect local conditions that impact on the risk of disease.

What data gathering facilities are required?

Sentinel site laboratories need to be improved throughout the world to allow accurate detection of emerging and reemerging disease and to record environmental data that may have a bearing on disease development. Long-term surveillance is needed because of the great complexity of interactions that exist between climate and disease.

There is a need to continue developing simple and inexpensive diagnostic tests (dip sticks, etc.) to determine the prevalence of disease in remote areas.

A commitment must be made not only to capturing good quality data, but also to transmitting these data to a central site, where they can be appropriately analyzed and stored. Biologic samples (human, pathogen and vector) must be preserved for reference and future study.

New Diseases or Better Detection?

Below are some currently recognized diseases caused by infectious agents that have either emerged or re-emerged and their emergence was linked to weather and climate. These diseases are not caused by new agents, but were unreported, unrecognized, or wrongly diagnosed in the past.

Hantavirus Pulmonary Syndrome was first recognized in 1993 in the Four Corners region of the U.S. Southwest. Retrospective studies, however, showed that cases had occurred in the late 1970's. Once the disease syndrome was linked to the Hantavirus, health workers in Rhode Island, Florida, Louisiana, and California correctly diagnosed the illness. Later, cases were found throughout South America. The 1993 cluster of cases in the Four Corners area was believed to be related to the prior El Niño. This cluster provided the key to discovery of disease that had been occurring regularly throughout nearly all of the Americas.

Leptospirosis is considered so uncommon in the U.S. that it was removed from the reportable disease list in 1995 -- fewer than 60 cases were reported in the U.S. that year. The outbreak in the summer of 1998 in the upper Midwest showed that Leptospirosis was not gone. In fact, when serologic tests were done in Baltimore, 16% of the tested people showed evidence of past or present infection. Similar serosurveys in Detroit showed infection in inner city children approaching 30%. Evidence indicates that because of the non-specific disease syndrome accompanying most Leptospirosis infections, physicians fail to think of the diagnosis and do not request serological tests. With early accurate diagnosis Leptospirosis is eminently treatable with antibiotics; however, undiagnosed infected individuals often receive extensive and expensive medical treatments in hospitals.

Lyme Disease is an illness characterized in its early stages by flu-like symptoms and a migrating rash and in its later stages by arthritis, carditis and neurologic disorders. It is caused by a spirochetal bacterium (Borrelia burgdorferi) transmitted by the bite of an infected Ixodes tick (Deer tick). Increasing numbers of cases have been reported since it was first recognized in1982 and over 103,000 cases have been reported to date.

These examples show that when the technology does not exist, a disease cannot be identified. Improvements in technology allow the assessment of the occurrence of a disease. But baseline measurements are still required to determine if the incidence rate for a disease is increasing or decreasing.

What will careful analysis of data provide?

Once quality longitudinal data have been obtained and relations between climate and disease established, these associations can be tested as hypotheses in other areas. Cross-sectional analyses can help to eliminate those factors that are not disease-related. For example, in some arid regions of Asia and Africa epidemics of malaria have been preceded by drought and food shortages, suggesting that famine-induced malnutrition is an important factor in the disease process. However, in South America malaria epidemics following drought occur without famine, implying that although drought and malaria are related, food shortages are not always a component in the disease process.

How good are current disease surveillance and diagnosis?

The number of laboratories doing disease surveillance on emerging and re-emerging infectious diseases is relatively small, and in many places they are very poorly funded. Improved surveillance could save lives.

Surveillance and diagnosis can be improved even in developed countries such as the United States, where an epidemic of 400,000 cases of cryptosporidiosis in Milwaukee was almost not recognized as a WBD epidemic, and a yellow fever victim infected in Brazil traveled to Memphis where the disease was only diagnosed postmortem.

Disease Models

What do disease models offer?

Simulation models that are developed to understand and predict the occurrence of either water-borne or vector-borne disease must take into account the myriad variables that can influence outbreaks of disease. Models can be used to forecast future disease epidemics (predictive models) or simply to provide a simple and clear way to understand the disease dynamics (heuristic or teaching models). Some principal limitations of predictive models are that they often do not include all the important variables and that the variables are not properly weighted in the model.

How many variables should a model include?

Models need to be constantly updated as quality data are obtained and new predictions are subjected to field-testing. Validations of models should continue until they produce accurate predictions. In addition to variables such as temperature, rainfall, humidity, ecology, socioeconomic status, demographics etc., models need to account for the ability of the host, the pathogen and the vector to adapt to gradually changing climatic conditions. As the impacts of variables on the dynamics of models are elucidated, the knowledge gained may point the way to new approaches of control.

What tools are available until truly predictive disease models are ready?

While rigorous predictive models that pertain to specific areas of the globe are awaiting full development, simplistic global models for VBD and WBD may be helpful. These simple models will provide a starting point to project the global level of disease expected, thus allowing health workers to intervene with vaccines, education, and vector control. These models need not deal solely with known causative factors but may be a sort of "black box" model of associations. For example, in northern latitudes measles outbreaks occur only when the temperature is low. Although temperature is not causative, the knowledge that this association exists helps public health planning and strategy.

Of what use are current models?

All of the participants agreed that models will always have inherent uncertainties. They also agreed that currently there is a lack of adequate, high quality data to support more predictive models. Some of the participants believe that models should be used for setting national policy or allocating resources only if policy-makers and the public are clearly informed about the limitations and uncertainties inherent in the model. Others felt that the models were too unreliable and should currently not be used for setting national policy nor for allocating resources.

Somewhat less caution is necessary in the use of models to identify knowledge gaps and guide research efforts. Research projects and sentinel sites should be able to provide the data necessary for evaluating models and making them more predictive. Unfortunately, there has been a tendency for the media and special interest groups to focus on models that predict extreme and disastrous outcomes. Greater emphasis on the limitations of predictive models is required in the public forum to prevent the dissemination of such skewed and inappropriate interpretations.

There are currently few VBD and WBD models capable of predicting disease epidemics. However, it may, in the future, be possible to devise such predictive models. In the mean time, the most useful contemporary models are those that examine the qualitative interactions of variables associated with a particular disease and provides a range of alternative outcomes.

Use of Predictive Models

Developing predictive models for disease risk assessment requires knowledge of where and when cases of disease occur and their relative position to the population as a whole. This is the traditional approach of epidemiology. An attempt is made using statistical analyses, to associate those distributions with environmental factors, as the distributions occurred before the outbreak. If these factors can be identified they can be plotted in relationship to the human population and the population at highest risk can be identified.

Workshop participant Glass and colleagues used this approach to examine the Hantavirus Pulmonary Syndrome outbreak in 1993. They were able to identify from satellite imagery where cases of disease were likely to occur nearly one year before the outbreak. Predictions were such that 95% of all the cases occurred in high-risk areas and nearly one third of the rural population was identified as at risk for possible infection.

What ongoing activities can serve to decrease the prevalence of VBD and WBD over the next few decades?

The workshop list included the following activities:

Research and Development

- Develop stable, easily administered, inexpensive vaccines.
- Develop pesticides and use them more effectively
- Develop more effective drugs to treat VBD and WBD.

- Improve understanding of interactions of climate, ecology, and infectious diseases. Continue research on vector ecology to improve predictive models.

Public Health

- Educate health workers and the general public in early recognition and prevention of outbreaks.

- Increase surveillance to detect outbreaks early and develop "early warning" models that will have predictive ability and that allow early mobilization of the public health agencies.

Community-based Opportunities

- For WBD, boil or filter water.

- Improve sanitation by keeping sewage away from potable water supplies.

- Improve personal hygiene, e.g., hand washing and waste disposal.

- Eliminate vector-breeding sites.

- Improve people's nutrition by changing or supplementing the diet.

National Opportunities

- Provide rural people with mechanisms to make and store potable water, e.g., Quick's containers that both stores water and generate hypochlorite solution to sterilize the water.

- Increase access to vaccines that are presently available.

- Develop the infrastructure and the political commitment to deliver vaccines: For example, the World Bank has already apportioned money for mass vaccinations in countries in Africa, but some countries have not begun a vaccination program so that the funds can be obligated.

- Improve infrastructure, particularly in urban areas, for increasing sanitation, water pipes, sewers, etc.

- Protect watersheds.

- Utilize the extensive climate, disease, and environmental databases of multiple agencies, such as the U.S. Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), U.S. Department of Agriculture (USDA), the Centers for Disease Control and Prevention (CDC), the World Health Organization (WHO) and U.S. Agency for International Development (USAID), for education and research.

International Opportunities

- Develop an international network for disease surveillance at key sentinel sites (e.g., transition zones in highland Africa, SE Asia and Latin America

Biological Control of Vectors

- Use fish in some areas for larval mosquito control.

- Use sterile males and megacyclops to control mosquito populations under experimental conditions; this method has had variable success.

- Use predators; these may be useful in very simple systems, but do not substantially regulate prey populations in many cases. Introduction of parasites to attack vector or reservoir populations may be effective in the short term but is often not effective over time.

Economic Improvement

- Improve the economy; this generally reduces VBD and often WBD by improving sanitation, health care, and education.

- Control breeding sites in development projects which can lead to breeding of vectors in water stored at construction sites and by water-collecting debris from an increasingly “throw-away” society.

Integrated Management

- Bring several approaches together at one time for more effective control.

- Seek out collaboration from other scientific disciplines to achieve more comprehensive integrated assessments.

Biographies of Workshop Participants

Menno Jan Bouma, M.D., Ph.D., is a clinical research fellow at the London School of Hygiene and Tropical Medicine, University of London in the Malaria program. His main research focus is on climate variability (particularly associated with El Niño) and epidemics of vector-borne diseases. Dr. Bouma has worked extensively with the Malaria Control Program for Afghan refugees in Pakistan.

Donald S. Burke, M.D., is Professor, Department of International Health, and Director, Center for Immunization Research, School of Hygiene and Public Health, Johns Hopkins University where he conducts basic, clinical, field and policy studies related to vaccines and to control epidemic infectious diseases. Prior to coming to Johns Hopkins, Dr. Burke worked for Walter Reed Army Institute of Research where he was responsible for research programs on infectious diseases of military importance and new technologies in biomedicine.

Gregory E. Gurri Glass, Ph.D., is Associate Professor in the Department of Molecular Microbiology & Immunology and Director of the GIS Laboratory, Program in Global Environmental Change, in the School of Hygiene and Public Health, the Johns Hopkins University. He also holds joint appointments in the Department of Epidemiology at Johns Hopkins and in the Biology Department at the University of New Mexico. His research interests involve identifying infectious agents and characterizing the maintenance and transmission of 'emerging' infectious diseases. A major focus of this work is identifying environmental factors preceding disease outbreaks that could be used for disease forecasting.

Samuel Myers, M.D., is an AAAS Science and Diplomacy Fellow working at the U.S. Agency for International Development. For two years, Dr. Myers worked as a field manager of a community-based project training a network of village workers in the Quomolangma Nature Preserve in Tibet in basic public health, curative care, and environmental management. The project provided the opportunity to show how environmental management can play an integral role in promoting public health in developing world communities. He continues to pursue strong interests in the linkages between environmental degradation, climatic variability, and human health.

Jonathan Patz, M.D., MPH, is Research Assistant Professor and Director of the Program on Health Effects of Global Environmental Change at the Johns Hopkins School of Hygiene and Public Health. He is double board-certified in Occupational & Environmental Medicine and in Family Medicine. Dr. Patz served as a principle lead author on assessments of this subject for the World Health Organization and for the United Nations IPCC. He is co-chair for the health sector of the new USGCRP National Assessment on Climate Change, and is Principal Investigator for an EPA funded, multi-institutional study on climate change health risks in the United States.

Paul Reiter, M.Phil., D.Phil., has spent nearly 30 years conducting research on the biology, behavior and control of arthropods that transmit human diseases, including field studies of the vectors of malaria, onchocerciasis, St Louis Encephalitis, Yellow Fever, and Dengue. He has served as a consultant on vectors and vector-borne diseases to the British Medical Research Council (MRC), WHO, PAHO, UNICEF, CARE, and many national governments around the world. He is presently Chief, Entomology Section of the CDC Dengue Branch in Puerto Rico. The influence of climate and weather on vector-borne disease has been a major topic of interest throughout his career.

Robert E. Shope, M.D. is Professor of Pathology at the WHO Center for Tropical Diseases, University of Texas Medical Branch. He has studied the epidemiology of vector-borne viral diseases such as Dengue, Japanese encephalitis, and Rift Valley fever for 43 years and co-directs the World Reference Center for Arboviruses in Galveston. He was co-author of the 1992 Institute of Medicine Report "Emerging Infections: Microbial Threats to Health."

Mark L. Wilson, Sc.D., is an Associate Professor of Biology and Epidemiology, at the University of Michigan. He is an ecologist and epidemiologist with broad research interest in infectious diseases, including the analysis of transmission dynamics, the evolution of vector-host-parasite systems, and the determinants of human risk. Recent efforts have been directed at various "emerging" diseases including ehrlichiosis, Lyme disease, raccoon rabies, and malaria associated with environmental change in the Middle East and Africa.

Annapolis Center Board Members Who Participated in the Workshop

VADM Harold M. Koenig, Medical Corps, U.S. Navy (Retired), *Workshop Chair,* Chairman and President of The Annapolis Center. Vice Admiral Koenig retired in June 1998 after serving more than 32 years in the Medical Department of the United States Navy. In his final assignment he served as the Navy's thirty-second Surgeon General, and Chief of the Bureau of Medicine and Surgery. He is certified by the American Board of Pediatrics in general pediatrics and pediatric hematology-oncology, and is a Certified Health Care Executive by The American College of Health Care Executives.

Mark J Utell, M.D., is Professor of Medicine and Environmental Medicine and Director of the Pulmonary/Critical Care and Occupational/Environmental Medicine Divisions at the University of Rochester Medical Center. He is also Associate Chairman of the Department of Environmental Medicine. His research interests have centered on the effects of environmental toxicants on the human respiratory tract. He is a recipient of the NIEHS Academic Award in Environmental and Occupational Medicine.

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About the Annapolis Center

The Annapolis Center supports and promotes responsible environmental, health, and safety decision-making.

The Center evaluates risk and cost-benefit analysis both to assist the public in understanding hazards and the relative risks they may present and to identify areas for emphasis in research and policy. The Center's *Annapolis Accords* provide vehicles to evaluate the quality of science underlying risk analysis and the quality of the policy foundation supporting risk management, as well as cost-benefit analysis. The Annapolis Center is a non-profit, 501(c)3 educational organization.

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