Report Summary

Under the Weather: Climate, Ecosystems, and Infectious Disease

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The observation that a change in weather can lead to the appearance of epidemic disease has been appreciated since the dawn of medical science. In modern times, our increasing abilities to detect and predict climate variations such as El Niño, coupled with mounting evidence for global warming, have fueled a growing interest in understanding the impact of climate on the transmission of infectious disease agents. Studying these linkages between climate and disease may yield insights into the factors that drive the emergence and seasonal or interannual variations in contemporary epidemic diseases and possibly into the potential future impacts of long-term climate change.

Understanding these linkages, however, can present a daunting research challenge. Climate-related impacts must be understood in the context of other influences on disease dynamics, such as rapid evolution of drug- and pesticide-resistant pathogens, swift global dissemination of microbes and vectors through expanding transportation networks, and deterioration of public health programs. In addition, the ecology and transmission dynamics of infectious diseases differ widely from one context to the next, making it difficult to draw general conclusions or compare results from individual studies. Finally, the interdisciplinary nature of this issue necessitates collaboration among scientists who may have little understanding of the capabilities and limitations of each other's fields. Such factors have contributed to vigorous debates on this topic in the scientific community. In response, a National Research Council committee was formed to address three tasks: to assess scientific understanding of the relationships between climate, ecosystems, and infectious diseases; to evaluate the potential for developing climate-based disease early warning systems; and to identify priorities for future research on this topic. The following is a summary of the committee's key findings and recommendations.

Linkages between Climate and Infectious Diseases

Disease Impacts of Weather and Climate Variability

The characteristic geographic distributions and seasonal variations of many infectious diseases are prima facie evidence that their occurrence is linked with weather and climate. Studies have shown that factors such as temperature, precipitation, and humidity affect the life cycle of many disease pathogens and vectors (both directly and indirectly, through ecologic changes) and thus can potentially affect the timing and intensity of disease outbreaks. However, the incidence of disease is also affected by factors such as sanitation and public health services, population density and demographics, land use changes, and travel patterns. The importance of climate relative to these other variables must be evaluated in the context of each situation.

Interpreting Observational and Modeling Studies

Numerous studies have shown an association between climatic variations and disease incidence, but such studies cannot fully account for the complex web of causation that underlies disease dynamics and thus may not be reliable indicators of future changes. Likewise, a variety of models have been developed to simulate the effects of climatic changes on incidence of diseases such as malaria, dengue, and cholera. These models are useful heuristic tools for testing hypotheses and carrying out sensitivity analyses, but they are not necessarily intended to serve as predictive tools and often do not take into account processes such as physical or biological feedback and human adaptation. Therefore, caution must be exercised in using these models to create scenarios of future disease incidence and to provide a basis for early warnings and policy decisions.

Potential Disease Impact of Global Climate Change

Changes in regional climate patterns caused by long-term global warming could affect the potential geographic range of many infectious diseases. However, if the climate of some regions becomes more suitable for transmission of disease agents, human behavioral adaptations and public health interventions could mitigate many adverse impacts. Basic public health protections such as adequate housing and sanitation, as well as new vaccines and drugs, may limit the future distribution and impact of some infectious diseases regardless of climate-associated changes. These protections, however, depend on maintaining strong public health programs and assuring vaccine and drug access in developing countries.

Climate Change and the Evolution and Emergence of Infectious Diseases

Another important but highly uncertain risk of climate change is its potential impact on the evolution and emergence of infectious disease agents. Ecosystem instabilities brought about by climate change and concurrent stresses such as land use changes, species dislocation, and increasing global travel could potentially influence the genetics of pathogenic microbes through mutation and horizontal gene transfer, giving rise to new interactions among hosts and disease agents. Such changes may foster the emergence of new infectious disease threats.

Extrapolating Climate and Disease Relationships

The relationships between climate and infectious disease are often highly dependent on local-scale parameters, and these relationships cannot always be extrapolated meaningfully to broader spatial scales. Likewise, the impact of seasonal to interannual climate variability on disease may not always provide a useful analog for the impact of long-term climate change. Ecologic responses on the timescale of an El Niño event, for example, may differ substantially from the ecologic responses and social adaptations expected under long-term climate change. In addition, long-term changes may influence regional climate

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variability patterns, hence limiting the predictive power of current observations.

Improved Modeling of Infectious Disease Epidemiology

Rapid advances in several disparate scientific disciplines may spawn radically new techniques for modeling infectious disease epidemiology. These innovations include satellite-based remote sensing of ecologic conditions, geographic information system (GIS) analytic techniques, inexpensive computational power, and molecular techniques to track the geographic distribution and transport of specific pathogens. Such technologies will make it possible to analyze the evolution and distribution of microbes and their relationship to different ecologic niches and may dramatically improve our ability to quantify the disease impacts of climatic and ecologic changes.

Early Warning Systems for Infectious Disease

Complementing "Surveillance and Response" with "Prediction and Prevention"

Current strategies for controlling infectious disease epidemics depend largely on surveillance for new outbreaks, followed by a rapid response to control the epidemic. In some contexts, however, climate forecasts and environmental observations could potentially be used to identify areas at high risk for disease outbreaks and thus aid efforts to prevent epidemics from occurring. Operational early warning systems are not yet generally feasible, due to our limited understanding of most relationships between climate and disease and limited climate forecasting capabilities, but establishing this goal will help foster the needed analytic, observational, and computational developments.

Effectiveness of Early Warning Systems for Disease

If relatively simple, low-cost strategies are available for mitigating risk for epidemics, it may be feasible to establish early warning systems based on a general understanding of associations between climate and disease. If the costs of mitigation actions are substantial, a precise and accurate prediction may be necessary, requiring more thorough mechanistic understanding of underlying relationships between climate and disease. In addition, the accuracy and value of climate forecasts will vary substantially, depending on the disease agent and the locale; and investment in sophisticated warning systems will be an effective use of resources only if a country has the capacity to take meaningful actions in response to such warnings and if the population is highly vulnerable to the hazards being forecast.

Components of an Effective Disease Early Warning System

Climate forecasts must be complemented by an appropriate set of indicators from ongoing meteorologic, ecologic, and epidemiologic surveillance systems. Together, this information could be used to issue a "watch" for regions at risk and subsequent "warnings" as surveillance data confirm earlier projections. Development of disease early warning systems should also include vulnerability and risk analysis, feasible response plans, and strategies for effective public communication.

Participants in Development of Early Warning Systems

The input of stakeholders such as public health officials and local policy makers is needed in the development of early warning systems to help ensure that useful forecast information is provided and that effective response measures are developed. The probabilistic nature of climate forecasts must be clearly explained to the communities using them, so that response plans can be developed with realistic expectations about the range of possible outcomes.

Recommendations for Future Research and Surveillance

Strengthen Research on Climate and Disease Linkages

Linkages between climate and infectious diseases are often poorly understood, and research to understand the causal relationships is in its infancy. Methodologically rigorous studies and analyses will likely improve our nascent understanding of these linkages and provide a stronger scientific foundation for predicting future changes. This research can best be accomplished through investigations that use a variety of analytic methods (including analysis of observational data, experimental manipulation studies, and computational modeling) and that examine the consistency of relationships between climate and disease in different societal contexts and across a variety of temporal and spatial scales.

Improve Disease Transmission Models

The most appropriate modeling tools for studying linkages between climate and disease depend on the scientific information available. For diseases in which there is limited understanding of the ecology and transmission biology but sufficient historical data on disease incidence and related factors, statistical-empirical models may be most useful. For diseases with insufficient surveillance data, first-principle mechanistic models that can integrate existing knowledge about linkages between climate and disease may have the most heuristic value. Models that have useful predictive value will likely need to incorporate elements of both approaches. Integrated assessment models can be especially useful for studying the relationships among the multiple variables that contribute to disease outbreaks, for looking at long-term trends, and for identifying gaps in our understanding.

Expand Epidemiologic Surveillance Programs

The lack of high-quality epidemiologic data for most diseases is a serious obstacle to improving our understanding of climate and disease linkages. These data are necessary to establish an empirical basis for assessing climate influences, establishing a baseline against which one can detect anomalous changes, and developing and validating models. A concerted effort should be made in the United States and internationally to collect long-term, spatially resolved disease surveillance data, along with the appropriate set of meteorologic and ecologic observations. Centralized, electronic databases should be developed to facilitate rapid, standardized reporting and sharing of epidemiologic data among researchers.

Coordinate Observational, Experimental, and Modeling Activities

Experimental and observational studies provide data necessary to develop and test models; and in turn, models can provide guidance on what types of data are most needed to further our understanding. The committee encourages the establishment of a climate and infectious disease research center dedicated to fostering meaningful interaction among the scientists involved in these different research activities through long-term collaborative studies, short-term information-sharing projects, and interdisciplinary training programs. The National Center for Ecological Analysis and Synthesis provides a useful model for the type of institution that would be most useful in this context.

Foster Interdisciplinary Research

Encouraging such efforts requires strengthening the infrastructure in universities and funding agencies for supporting interdisciplinary collaboration among climate modelers, meteorologists, ecologists, social scientists, and a wide array of medical and public health professionals, as well as developing educational programs in the medical and public health fields that explore environmental and socioeconomic factors underlying the incidence of infectious disease. A few programs have been established in recent years to foster the application of remote sensing and GIS technologies to epidemiologic investigations. The committee applauds these efforts and encourages all the relevant U.S. federal agencies to support interdisciplinary research programs on climate and infectious disease, along with an interagency working group to ensure effective coordination among programs. The U.S. Global Change Research Program could provide an appropriate forum for this type of coordinating body if the Centers for Disease Control and Prevention and the National Institute of Allergy and Infectious Disease were to become actively involved.

In closing, the committee emphasizes that there will always be an element of unpredictability in climate variations and in infectious disease outbreaks. Thus, a prudent strategy for all governments is to set a high priority on reducing overall vulnerability to infectious disease through strong public health programs.

The full report, Under the Weather: Climate, Ecosystems, and Infectious Disease, contains a detailed discussion of all the issues mentioned above. Copies of the report can be ordered from the National Academy Press, either through their website at http://www.nap.edu/catalog/10025.html or by calling 1-888-624-8373.

Upcoming Events

The Crisis of Neglected Diseases: Developing Treatment and Ensuring Access

The Graduate Center, City University of New York
Thursday, October 4, 2001

This international conference is sponsored by Médecins Sans Frontières/Doctors Without Borders. Neglected diseases such as malaria, tuberculosis, and sleeping sickness kill millions of people around the world each year, yet research and development of new treatments is at a virtual standstill. Join leading international researchers, policy makers, public health experts, and pharmaceutical representatives in addressing this global crisis.

Additional information is available at www.neglecteddiseases.org or by e-mailing access-nyc@newyork.msf.org or by calling 212-847-3153.

International Conference on Emerging Infectious Diseases, 2002

The National Center for Infectious Diseases, Centers for Disease Control and Prevention, has scheduled the third International Conference on Emerging Infectious Diseases (ICEID2002) for March 24 - 27, 2002, at the Hyatt Regency Hotel, Atlanta, Georgia, USA. More than 2,500 participants are expected, representing many nations and disciplines. They will discuss the latest information on many aspects of new and reemerging pathogens, such as West Nile virus and issues concerning bioterrorism.

More information about the conference will be posted soon at http://www.cdc.gov/ICEID/index.htm

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