



American Public Health Association

Working for a Healthier World

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October 22, 2007

The Honorable Barbara Boxer
Chairman
U.S. Senate Committee on Environment and Public Works
410 Dirksen Senate Office Bldg.
Washington, DC 20510-6175

Dear Chairman Boxer:

The American Public Health Association (APHA) is the oldest and most diverse organization of public health professionals in the world, dedicated to protecting all Americans and their communities from preventable, serious health threats and assuring community-based health promotion and disease prevention activities and preventive health services are universally accessible in the United States. I write on behalf of APHA to express strong support for your efforts to highlight the potential and likely public health effects of global climate change.

First off, I want to make it clear that climate change is a public health issue. From changes in vector borne diseases to impacts on drinking water supply to extreme weather events, we are already seeing the effects of climate change on the health across the globe. According to the World Health Organization, deaths from extreme heat, air pollution and infectious diseases are already occurring around the world. The public health community must be involved in every effort to not only mitigate the negative health effects of climate change, but also to adapt to those changes that are already occurring.

We must also note that the world's most vulnerable, those populations who are already at increased risk from death and disease, such as communities of color, the elderly, young children and the poor will face the highest burden of death and disease from climate change. These communities already face poor health conditions – including lack of access to clean air and water and unhealthy living conditions that will be exacerbated by climate change.

APHA believes that the public health community has a critical role to play in advocating for both mitigation of climate change and adaptation to the negative public health effects that will result. But we must also ensure that our nation's public health workforce is educated about the impacts of global climate change. We believe that legislative proposals to address climate change should address both mitigation and the negative health consequences that are already taking place. Any legislation should support alternative energy use and decreased emissions and also healthy community design. Decreasing Americans' reliance on cars by creating more walkable and bikeable communities will decrease greenhouse gases and also has other health benefits, including decreased asthma rates and reduced obesity. We also

strongly support efforts to provide our already over extended local, state and federal public health workers and agencies with the training and increased resources they will surely need to be able to address the public health challenges created by global climate change.

Thank you again for your leadership on this critical public health issue. We look forward to working with you and your colleagues to ensure that the public health consequences of climate change are at the forefront of your discussions as you move forward in developing legislation to address this unique challenge. Please don't hesitate to contact APHA if we can be of any assistance in that process.

Sincerely,

A handwritten signature in black ink, appearing to read "Georges C. Benjamin". The signature is fluid and cursive, with a large, stylized initial "G".

Georges C. Benjamin, MD, FACP, FACEP (Emeritus)
Executive Director

NACCHO

National Association of County & City Health Officials

October 23, 2007

The Honorable Barbara Boxer
Chairman, Senate Environment and Public Works Committee
456 Dirksen Senate Office Building
Washington, DC 20510

Dear Chairman Boxer:

Thank you for holding a hearing October 23 on the human health impacts of global warming. The National Association of County and City Health Officials (NACCHO) believes that climate change has serious far-reaching health implications for this and future generations. The impacts of climate change are felt first and foremost at the local level and local health departments are working to address these impacts. Many local health officials are educating the public about the health impacts of climate change in order to raise awareness about problems that are already occurring and are expected to worsen if climate change is not addressed.

Environmental changes that can be expected from climate change include: extreme temperatures, extreme weather events and natural disasters, worsened air quality, shortages of food and water, increased vector borne and zoonotic diseases, stratospheric ozone depletion and social and economic impacts on community health and well-being.

Health impacts are associated with many of these environmental changes. Temperature extremes can cause cold and heat-related illnesses and deaths, which are disproportionately felt by vulnerable populations. As seen in Hurricane Katrina in 2005, communities can be displaced and their residents suffer death, injury and illness as well as social, emotional and mental health stress as a result of natural disasters. The aftermath of this catastrophic event demonstrated that communities affected by a natural disaster can take years to rebuild after their fragile infrastructure is destroyed.

Other health impacts include increases in chronic diseases such as asthma, allergies and other respiratory illness resulting from increased air pollution. Drought can cause increased concentrations of pollutants and freshwater pathogens in drinking water supplies. Increases in vector borne and zoonotic diseases can produce changed patterns of disease like West Nile Virus with a shorter respite due to colder weather killing off mosquito populations.

Local health officials have a role to play in preparing for and combating the adverse health impacts caused by climate change. These problems will transpire differently in different regions of the country. Local health departments are engaged in monitoring the public's health, investigating infectious water-, food- and vector-borne illnesses and taking steps to reduce the incidence of disease. Since the terrorist attacks of 9/11 and the anthrax attacks following soon after, local health departments have taken on the role of public health emergency



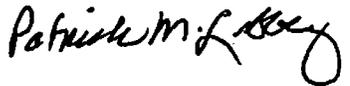
Public Health
Prevent. Promote. Protect.

preparedness in a more focused way. Local health departments are preparing their employees and communities to respond to all hazards, including natural disasters resulting from global climate change.

In a natural disaster, local health officials work with local emergency management officials and other community leaders to make sure that public health concerns are addressed and the public's health is protected. Local health departments are currently conducting exercises and drills so that they will be prepared in any emergency, be it bioterrorism, a hurricane, flood or earthquake or an infectious disease like pandemic influenza. In an emergency, all public health personnel will be called upon, regardless of their usual day-to-day responsibilities. This means that in an emergency that lasts for an extended period of time, local public health staff may not be able to attend to their normal duties in the area of chronic or infectious disease, maternal and child health, immunizations or other public health services. This would have an immediate impact on the community as levels of immunization and other preventive services decrease and chronic and infectious disease rates rise.

In closing, local health departments are acutely aware of the health impacts of climate change and are actively preparing for these health impacts and monitoring changes in chronic and infectious disease that are expected to increase in the coming years. We thank you again for your leadership on this issue and look forward to working with you to address the pressing needs of local communities.

Sincerely,

A handwritten signature in black ink that reads "Patrick M. Libbey". The signature is written in a cursive style with a large, looping "L" at the end.

Patrick M. Libbey
Executive Director



Tel direct: +41 22 791 5526
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In reply please
refer to: PHE- H11/372/48

Your reference:

The Honourable Barbara Boxer
Chairman
Committee on Environment and Public
Works
United States Senate
410 Senate Dirksen Office Building
Washington, DC 20510-2602
USA

22 October 2007

Madam,

I have the honour to respond to an enquiry from your staff related to the latest consultations and information within the international health community and the World Health Organization (WHO) on the subject of public health and climate change, I would like to take the opportunity to brief you on this matter.

Evidence on health risks from climate change.

The WHO has run an active programme on climate change since the late 1980s. Over this period, WHO has produced a wide range of reports reviewing the evidence that climate change poses to health, and has an increasing focus on providing guidance to member states on protection from these risks.

The WHO position on the science of climate change is as described by the Intergovernmental Panel on Climate Change (IPCC); i.e. that the earth is warming, with more extreme events (such as heat waves, floods and droughts), that human actions are the dominant cause of these changes, and that these trends will continue throughout the next Century

WHO has carried out both qualitative reviews and quantitative assessments of the health risks posed by climate change. The organization concludes that the health hazards posed by climate change are significant, wide-ranging, distributed throughout the globe, and difficult to reverse. The climate change that has occurred so far is already having health impacts, for example influencing the European heat wave of 2003 which killed over 35,000 people, and facilitating conditions for malaria epidemics in the East African highlands. Climate change affects some of the most important risk factors for global public health, such as the availability of freshwater, and some of the largest disease burdens, particularly those of childhood, such as malnutrition, diarrhoea and malaria.

cc: Permanent Mission of the United States of America to the United Nations Office and other International Organizations in Geneva .../4

منظمة الصحة العالمية • 世界卫生组织

Although all populations are vulnerable, the greatest risks are to populations living in small-island developing states, mountain regions, water-stressed regions, mega cities in developing countries (particularly the Asian mega-delta cities), and those that are poor, and poorly protected by health services. The greatest concern is for Africa, which has the highest burden of climate-sensitive diseases, the weakest public health capacity to respond to the additional impact, and where climatic effects on socioeconomic development will have the largest impact on health and wellbeing.

Climate change is expected to bring some health benefits (some reduction in winter deaths in elderly populations in high latitudes), but these are outweighed by the negative impacts, both now and for the foreseeable future. A WHO quantitative assessment concluded that even the modest degree of climate change that has occurred since the mid 1970s may already have been causing over 150,000 excess deaths annually by the year 2000. The burden is overwhelmingly concentrated on diseases of children in poorer countries; i.e. those who have contributed least to the causes of climate change.

Compared to the developing world, the US population is expected to be protected from many of the health risks of climate change, due to generally high socioeconomic standards, and effective public systems. These should ensure, for example, that endemic malaria does not return to the USA. However, significant risks remain, particularly through an increasing frequency and intensity of weather-related natural disasters such as heat waves, bushfires and hurricanes, water scarcity affecting infectious diseases, and potentially loss of livelihoods. These risks can be expected to be most severe among those who are living in poor socioeconomic conditions, have pre-existing disease conditions, and/or lack of access to healthcare and other support services.

The US population may also be put at risk through the health effects of climate change outside US borders. These include increasing infectious disease and other health risks for US travellers and immigrants, potential geopolitical instability arising from increased risks of conflict over dwindling natural resources, and increased numbers of refugees displaced by drought or flooding.

Climate change also threatens to undermine the effectiveness of US support to health goals in the developing world, by increasing the risks of climate-sensitive diseases and conditions such as malaria, diarrhoea and malnutrition in Africa, and by reducing the effectiveness of support in sectors such as water supply and agriculture.

The need for an effective response:

WHO has concluded that climate change brings major new challenges to health security, and will increase the costs and difficulties of disease control. As the evidence for climate change and associated health impacts has increased, WHO is receiving increased requests for guidance and assistance from its member states, through the WHO Regional Committee meetings. Humanitarian agencies such as the International Federation of the Red Cross and Red Crescent are recording a rapidly increasing demand for operational support to weather-related natural disasters, such as the recent extreme floods in India and across central Africa.

.../4

A well planned approach by the international community could minimize these damages, and bring both immediate and long-term gains for public health. Any effective response to protect health from climate change will need to include both adaptation, to protect health from the climate change that is now inevitable, and climate change mitigation, in order to slow and eventually to halt the increase in health hazards.

Because some climate change is now inevitable, it will be necessary to strengthen health systems to protect public health from the associated risks. Most of the impact will be from exacerbations of existing problems. In the view of WHO, the most effective response will be mainly through strengthening core public health interventions, based within existing health systems, rather than either setting up parallel functions that are specific to climate change, and that could distract attention and resources from these essential activities.

This strengthening should include a greater emphasis on environmental and socioeconomic determinants of health risks (such as disaster risk reduction), and actions specifically within the formal health sector, such as enhanced environmental health protection, strengthened disease surveillance and response, and improved health action in crises. These can be supported by selected "new" interventions for specific risks, such as heat wave and vector-borne diseases early warning systems, and supporting development choices that enhance health in related sectors such as agriculture and water management. All of these actions would benefit health now, as well as reducing vulnerability to future climate change.

For long-term health protection, it will also be necessary to reduce climate change itself, mainly by cutting greenhouse gas emissions. This will also create opportunities for immediate health gains. For example, the use of cleaner energy sources would reduce deaths from indoor and outdoor air pollution, and promotion of sustainable transport systems and urban development could reduce the rapidly growing disease burden related to physical inactivity. The IPCC concludes that even a conservative accounting of the health benefits (considering only air pollution) would largely offset the investment costs necessary to reduce greenhouse gas emissions.

Opportunities for enhanced health protection from climate change in the USA and internationally:

In response both to the accumulating scientific evidence and the demands of member states, WHO has recently stepped up its activities on health protection from climate change, including increasing its capacity-building activities across member states. WHO is developing a *Global Framework on Health Protection from Climate Change*, recently highlighted and supported by the Spanish Prime Minister at the UN High Level Meeting on Climate Change on 24th September 2007. WHO has announced that "Health Protection from Climate Change" will be the theme of the World Health Day 2008, and the WHO 60th anniversary year. It will therefore be a focus for awareness raising and increased activity on this issue across the international health community.

WHO already works closely with US agencies, notably the US Centers for Disease Control and Prevention, and the US Environmental Protection Agency. WHO proposes to maintain and enhance this technical collaboration, for example through consultation during the further development of the *Global Framework on Health Protection from Climate Change*, and sharing of expertise. This would strengthen the international effort on this issue, through better

access to US expertise to address global health threats. It should also contribute to US goals, such as reduction of risks of disease and geopolitical threats from abroad, and enhancement of the effectiveness and the visibility of US international aid for health and development.

If you, Madam Chairman, or the Senate Committee on Environment and Public Works would like a briefing in person at some point in the future on these or other subjects related to world health, please do not hesitate to contact me or my colleague, Dr Nelle Temple Brown, in the WHO Liaison Office in Washington, DC (templebrown@who.int, 202-974-3299).

Please accept, Madam, the assurance of my highest consideration.



Dr David L. Heymann
Assistant Director-General for
Communicable Diseases, and
Representative of the Director-General for
Polio Eradication

ASTHO Position Statement- Climate Change and Public Health

Position

Climate Change and Public Health

There is widespread scientific consensus that the world's climate is changing. The Association of State and Territorial Health Officials (ASTHO) supports the scientific consensus put forward within the Intergovernmental Panel on Climate Change Fourth Assessment Report that the weight of evidence demonstrates that anthropogenic factors have and will continue to contribute significantly to changing the world's climate. The anticipated health effects related to climate change include death and illness from heat waves, injuries from catastrophic weather events, increased air pollution with concomitant rises in respiratory and cardiovascular diseases, and an increased incidence of vector- and water-borne diseases. Recent climate-related challenges, from extreme weather events to changing patterns of communicable disease, have already demonstrated the critical need to improve public health capacity to identify, prevent, and respond to climate related threats.

ASTHO recognizes that climate change has serious far-reaching implications for the health of this and future generations. ASTHO asserts that climate change has the potential to place unprecedented demands upon public health infrastructure in the United States and abroad. ASTHO asserts the need for enhanced and specific preparedness of federal, state and local health systems to cope with the present and future challenges of climate change.

ASTHO acknowledges that there are uncertainties regarding the projected impacts of climate change on health. The actual effects of climate change on population health are influenced by many confounding factors, including socioeconomic status of individuals and communities, demographic structure of the population, geographical location, access to medical care, and adaptation measures implemented to reduce negative impacts. Recognizing these uncertainties, ASTHO supports action to adequately bolster public health infrastructure to prepare for future challenges.

ASTHO Supported Response to Climate Change

ASTHO advocates strong coordination and collaboration across all tiers of governmental public health to improve understanding of climate change and enable optimal preparation and response to related health impacts. ASTHO urges federal, state and local government bodies, including legislatures, to provide leadership in the development and coordination of public health policy and reform of existing policies, to address health impacts related to climate change.

Understanding and Preparedness

ASTHO supports enhancing the ability of federal, state and local health agencies to understand and prepare for the health impacts linked to climate change in their jurisdictions. ASTHO urges the federal government to provide leadership, resources and programs to support state health agencies in developing educational initiatives to raise awareness of the link between climate change and human health among public health professionals and prepare for the potential health impacts of climate change with enhanced planning, surveillance initiatives, and programs.

ASTHO supports investment in research to better understand the potential health impacts of climate change and to develop and enhance surveillance and response systems to mitigate health impacts. These efforts should include, but not be limited to, initiating and promoting scientifically based health programs; developing practice standards; identifying promising

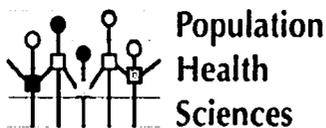
practices and success stories; developing decision support systems that enable agencies to predict, anticipate and model events; and developing early warning systems that enable rapid response.

Education and Outreach

ASTHO urges public health agencies and professionals to inform communities, policy makers, other government departments and industry of the public health impacts of climate change. Public health leaders must be at the forefront of all mitigation and adaptation actions related to climate change. ASTHO encourages public health agencies and professionals to actively engage with all stakeholders to insure consideration of the potential health impacts in all aspects of behavior, consumption and decision making that may contribute to climate change. ASTHO urges public health agencies and professionals to actively promulgate policies towards preventing and mitigating the public health impacts of climatic change.

Reference

1. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. April 6th, 2007.



Population
Health
Sciences



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October 22, 2007

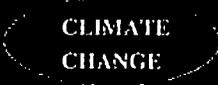
Honorable Senate Members of the Committee on Environment and Public Works:

Thank you very much for inviting me to testify at the Senate hearing on Climate Change and Health (and apologies that your staff could not reach me by phone last Thursday afternoon). I have worked on the health effects of climate change for the past 14 years. I co-chaired the Health Expert Panel of the U.S. National Assessment on Climate Variability and Change, have served as a Lead Author for the U.N. Intergovernmental Panel on Climate Change (IPCC) assessment reports of 1995, 2001, and 2007, and have co-authored monographs on this subject for the World Health Organization (WHO) along with numerous other peer reviewed scientific publications. Our research team has studied the relationship between climate and heat related mortality, ozone air pollution, vector- and water-borne diseases, and the interaction between climate and land use change effects on disease emergence or resurgence.

It is quite clear that public health is a core central concern regarding climate change (and often is overshadowed by more of the physical climatic and water/agricultural aspects of global warming). Climate change represents one of our most challenging threats to the health of Americans for several reasons listed below:

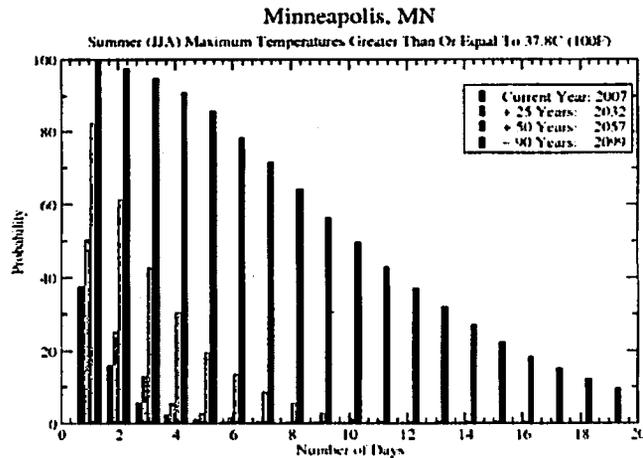
- Multiple exposure pathways:** Climate change can affect our health either from direct heatwaves and severe storms to ground level ozone smog pollution and airborne allergens, as well as many climate sensitive infectious diseases. Acting in synergy with other sector impacts –especially related to water and food security issues – climate change is NOT the ‘single agent’ toxin or infection to which we are used to addressing. *Such broad and interconnected exposures will therefore require a well-coordinated and comprehensive disease prevention strategy.*

- Health impacts for the United States:**
The changing climate can have both adverse and beneficial outcomes. Examples of benefits may include reduced cold-

HEALTH EFFECTS OF CLIMATE CHANGE		
 Temperature Rise ¹ Sea level Rise ² Hydrologic Extremes ¹ 3°C by yr. 2100 ² 40 cm " " IPCC estimates Patz, 1998	Urban Heat Island Effect	Heat Stress Cardiorespiratory Failure
	Air Pollution & Aeroallergens	Respiratory diseases, e.g., COPD & Asthma
	Vector-borne Diseases	Malaria Dengue Encephalitis Hantavirus Rift Valley Fever
	Water-borne Diseases	Cholera Cyclospora Cryptosporidiosis Campylobacter Leptospirosis
	Water resources & food supply	Malnutrition Diarrhea Toxic Red Tides
	Mental Health & Environmental Refugees	Forced Migration Overcrowding Infectious diseases Human Conflicts

related mortality and Rocky Mountain Spotted Fever in the Southeastern U.S. However, according to the health expert teams for the IPCC's 1995, 2001 and 2007 reports, they conclude that on balance, the health effects from climate change will be adverse. Observations and projections include, for example:

- a. During the 1995 Chicago heat wave over 700 excess deaths occurred; future projections for Chicago are for an increase in heatwaves and a study of Los Angeles projected a 3-fold increase for heatwaves in LA by this century. According to the IPCC, major portions of the U.S.



are expected to have a higher number of extremely hot days (figure above shows probability for days >100°F in Minneapolis).

- b. A study on air pollution in the Eastern U.S., found a projected 68% increase in Ozone 'Red Alert' days east of the Mississippi by the 2090s due to the influence of warming alone (and according to the IPCC, stagnant air masses are projected to increase as well which could exacerbate this problem).
- c. Studies have documented an increase in ragweed pollen production with warming temperatures and higher levels of CO₂ in the air.
- d. Of reported water-borne diseases in U.S., 67% were preceded by very heavy rainfall; projections are for increases in extreme rainfall and runoff, placing more risk on already deteriorating conditions of water systems in many cities.
- e. While West Nile Virus has spread across the country by bird migration, the highest transmission locations were those with unseasonably hot temperatures.

3. Dangerous synergies are of concern, for example:

- a. The 'urban heat island' effect over sprawling cities with asphalt highways
- b. Destruction of storm-buffering coastal wetland, e.g, near New Orleans
- c. Increased allergens in air along with a lengthening ozone pollution season

4. Changing disease risks internationally do affect the U.S. Many poor nations of the world are expected to suffer even more health consequences due to climate change compared to the U.S. With global trade and transport, however, disease flare-ups in any part of the world can potentially reach the U.S. Additionally, further climate extremes, e.g. droughts and storms, can further stress environmental resources by destabilizing and subsequently becoming a security risk both internally and to other nations.

5. **Intergeneration aspect:** while climate change is already affecting health; according to the WHO, annually over 166,000 deaths and 5 million 'disability adjusted life years' are already occurring just from warming of the past 30 years (note that these figures apply to *only four* selected health outcomes, and therefore, should be treated as extremely conservative). According to WHO, these numbers are expected to double by the year 2030.
6. **Environmental justice:** Simply consider Hurricane Katrina and New Orleans.

Recommendations:

- 1) **There has been a dearth of funding for research or strategic prevention programs in the area of climate change and health.** To date, Health and Human Services (HHS) has been especially absent on this serious and widespread issue and should become a major federal agency partner or lead in the effort to protect the American public from health risks posed by climate change.
 - a. CDC should fund state, territorial and local health agencies in health preparedness for climate change.
 - b. NIH and CDC should sponsor substantive research to improve predictive capability and establish 'centers of excellence' on climate change & health.
 - c. Coordinated efforts on climate change & health should cut across agencies – EPA, NASA, and NOAA have already been engaged on the issue, though funding historically has been insufficient in the health impacts area compared to the physical science end of the climate change problem.
- 2) **Strategic planning should take place across federal, state, and local government, academia, and the private sector to look for win-win solutions in combating climate change.** For example, 60% of Americans do not meet recommended daily exercise requirements and our cities are far too dependent on transportation by automobiles. If we could make our cities more livable –that is, better for walking and biking, and with effective multi-modal transportation, we could potential realize benefits of exercise fitness (especially key since obesity is epidemic now), reduced air pollution, and reduced greenhouse gas emissions.
- 3) **The Federal government should follow the lead of several states and >600 mayors to reduce greenhouse gas emissions with mandatory measures.** With climate change upon us, *energy policy has become one and the same as public health policy.*

Thank you very much for accepting my written testimony.

Sincerely,



Jonathan Patz, MD, MPH, Director, Global Environmental Health
Associate Professor of Environmental Studies and Population Health Sciences

Health Effects of Climate Change

Andy Haines, MD, MBBS

Jonathan A. Patz, MD, MPH

HUMANS ARE NOW MAKING UNprecedented changes to the global environment. Economic development has been fostered by the use of fossil fuels but the accompanying accumulation of greenhouse gases, particularly carbon dioxide and methane, has implications for the world's climate (BOX).¹ Since the 1850s when temperature records began, the world has warmed by approximately 0.6°C, largely in the last 3 decades. The United Nations Intergovernmental Panel on Climate Change (IPCC) projects an increase of between 1.8°C and 5.8°C and an increase in sea levels between 9 and 88 cm during the next century.¹ Warming is likely to be greater at the poles than at the equator. The residence time in the atmosphere of carbon dioxide exceeds 100 years; therefore, our actions affect the prospects of future generations.

The IPCC concluded, "There is now good evidence that regional changes in climate, particularly increases in temperature, have already affected a diverse set of physical and biological systems in many parts of the world."¹ Earlier break-up of ice on rivers and lakes and movements of plant and animal ranges to higher altitudes are some examples. There is also potential for large-scale and potentially irreversible changes in Earth systems, such as slowing of the ocean circulation that transports warm water to the North Atlantic, large-scale melting of the Greenland and west Antarctic ice sheets, and ac-

celerated global warming because of the positive feedbacks of the carbon cycle (eg, methane released from thawing arctic tundra). The probability of these events may be very low but is likely to be affected by the speed and duration of climate change. The potential pathways by which climate change may affect health are shown in the FIGURE.²

Thermal Stress

Major increases in the frequency of heat waves with climate change may occur. For example in England, the heat wave of 1976 was a very rare event (occurring once every 310 years) that will probably occur every 5 to 6 years by 2050.³ The urban heat island effect results in the temperatures being somewhat higher in cities than in suburban and rural areas, primarily because of the abundance of heat-retaining surfaces such as concrete and black asphalt. In 1995, the week-long heat wave in Chicago, Ill, caused more than 700 heat-related deaths.⁴ Much of the excess mortality from heat waves is related to cardiovascular, cerebrovascular, and respiratory disease and is concentrated in elderly persons and individuals with preexisting illness. A proportion of these deaths occur in susceptible people who are likely to have died in the near future but there also may be substantial numbers of potentially preventable deaths. The thousands who died in the recent European heat wave show current failings in dealing with this threat.⁵

In the United States, cities with cooler climates tend to experience more heat-related deaths than those with warmer climates^{6,7} because populations can acclimatize to some extent to different levels of temperature. Acclimatization is

through a range of mechanisms, physiological, behavioral, technological, but it is not yet clear how much such processes will diminish the adverse effects of climate change. The extent to which increases in heat-related mortality will be offset by reductions in cold-related mortality is likely to vary by location.

Floods and Droughts

Populations in developing countries are likely to be particularly vulnerable to floods because of the habitation of high-risk areas, such as flood plains and coastal zones, weak public health infrastructure, and proportionally higher economic damage. The health impacts include physical injury and increases in diarrheal diseases, particularly in developing countries where malnutrition may also increase. Increased incidence of respiratory infections may be caused by crowding of populations. Overgrowth of molds may also cause respiratory symptoms. Increases in psychiatric disorders, such as anxiety and depression, often occur, probably related to damage to the home environment and economic losses. Increases in suicide have been reported and behavioral disorders may increase in children.⁸ An increase in sea levels would pose even added risks to coastal communities.

Drought may have an impact on health in developing countries be-

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Contempo Updates Section Editor: Sarah Pressman Lovinger, MD, Fishbein Fellow.

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Box. Projected Changes During the 21st Century in Extreme Climate Phenomena and Their Likelihood***Simple Extremes**

Higher maximum temperatures; more hot days and heat waves† over nearly all land areas (very likely‡)

Higher (increasing) minimum temperatures; fewer cold days, frost days, and cold waves† over nearly all land areas (very likely‡)

More intense precipitation events (very likely‡ over many areas)

Complex Extremes

Increased summer drying over most mid-latitude continental interiors and associated risk of drought (likely‡)

Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities (likely‡ over some areas)§

Intensified droughts and floods associated with El Niño events in many different regions (likely‡)

Increased Asian summer monsoon precipitation variability (likely‡)

Increased intensity of mid-latitude storms (little agreement between current models)†

*Adapted with permission from Houghton et al.¹ Likelihood refers to judgmental estimates of confidence used by the Intergovernmental Panel on Climate Change (IPCC) Working Group I in its Third Assessment Report.

†Information from the IPCC Working Group I, Technical Summary.¹

‡Summary for policy makers: very likely (90%-99% chance); likely (66%-89% chance).

§Changes in regional distribution of tropical cyclones are possible but have not been established.

cause of its adverse effects on food production and in hygiene because of use of water primarily for cooking rather than cleaning. Outbreaks of malaria can also occur during droughts as a result of changes in vector breeding sites.

El Niño and Health

El Niño events have probably occurred for millennia. The name arises from the observation that warm water appears off the coast of Peru and Ecuador, most noticeably around Christmas (El Niño thus refers to the infant Jesus). On an irregular basis between every 2 and 7 years, the warming is anomalous and persists for 12 to 18 months. It may be followed by a cold phase called La Niña. El Niño events are consistently associated with heavy rainfall and flooding on the west coast of Latin America but in addition have important distant linkages with climate in other parts of the world; this occurs because altered convection loops at the equator change weather patterns. For example, during El Niño years, drought usually occurs in South-

east Asia, Indonesia, and southern Africa, whereas flooding may occur in the southwest United States, Argentina, and Kenya.

There have been a number of time series analyses during more than 1 event that suggest a range of impacts of the El Niño cycle on health.⁹ The most consistent relationships are with malaria epidemics in parts of Latin America and South Asia. The effects may be mediated by short-term atypical climatic conditions (eg, rainfall in arid regions and drought in more humid climates). The incidence of many other diseases, such as dengue, hantavirus infections, cholera, and Murray Valley encephalitis, may be influenced by El Niño, although the quality of the evidence is variable.⁹

There is a relationship between the El Niño phenomenon and the population affected by natural disasters, particularly droughts, on a global scale.¹⁰ It is not fully known how the El Niño phenomenon will be affected by climate change, but the IPCC has suggested that associated droughts and floods will be intensified (Box).

Air Pollution

The impact of some air pollutants on health appears to be stronger during summer months or during high temperatures,¹¹ but this is not a universal finding. Ozone levels tend to be higher at higher temperatures and some studies have suggested that ozone contributes to the excess mortality observed.¹²

Climate change is likely to affect the risk of forest fires, which in some locations (eg, Malaysia and Brazil) have been associated with the increased risk of outpatient visits for respiratory disease. An increase in emergency department visits for asthma, bronchitis, and chest pain occurred after the 1998 wildfires in Florida.¹³

Allergens

Warmer winters may result in an earlier start of the grass pollen season, and birch pollen concentrations may also increase. Also, rising carbon dioxide has been shown to increase the timing and release of biogenic allergens (eg, ragweed) in both indoor and in situ studies.¹⁴ Climate change may thus increase the incidence of allergic rhinitis, the intensity and duration of symptoms, or both.¹¹

Infectious Diseases

Changes in temperature, humidity, rainfall, and sea level rise could all affect the incidence of infectious diseases. Mosquitoes, ticks, and fleas are sensitive to subtle temperature and humidity changes. But vector-borne diseases are also dependent on many other interacting factors. Although there has been a resurgence of infectious diseases in recent years, it is unclear that climate change has played a significant role. Other factors such as the movement of human and animal populations, the breakdown in public health infrastructure, changes in land use, and the emergence of drug resistance have been contributory.¹⁵

The TABLE illustrates the potential impacts of climate change on vector-borne and rodent-borne disease transmission, focusing on malaria and dengue.¹¹ Malaria is currently present in 101 countries, and 40% of the world's

population lives in areas with malaria.¹⁶ Malaria claims 1 to 2 million lives annually, most of which are those of children. In Africa, distribution of the disease is largely limited by climate, except at the southern limit.¹⁷ In many parts of the world, effective public health systems ensure that malaria transmission remains well within the climatic limits of its distribution.¹⁷

There are different approaches to modeling malaria risk with climate change, including biological models building from known disease transmission dynamics and statistical empirical approaches based on malaria's current epidemiology. A study using a biological model suggested, based on specific climate scenarios, that there might be a global increase of 260 to 320 million people in 2080 living in a potential transmission zone, against a baseline population expectation of about 8 billion.¹⁸

This represents a 2% to 4% increase in the number of people at risk of malaria.

Use of a statistical empirical approach suggested no significant net change by 2080 in the proportion of the world's population living in actual malaria transmission zones.¹⁹ But this approach may not capture potential climate change effects on the seasonality of malaria in areas where transmission already occurs.

Using the latest climate change scenarios, recent modeling experiments suggest a 5% to 7% potential increase in malaria distribution in Africa by 2100, primarily expanding malaria's altitudinal reach rather than latitudinal. An overall increase in person-months of exposure risk to malaria was 16% to 28%, largely because of a prolonged transmission season. This most recent study used data that were spatiotemporally validated against parasite sur-

veys and represents findings following extensive analysis.²⁰

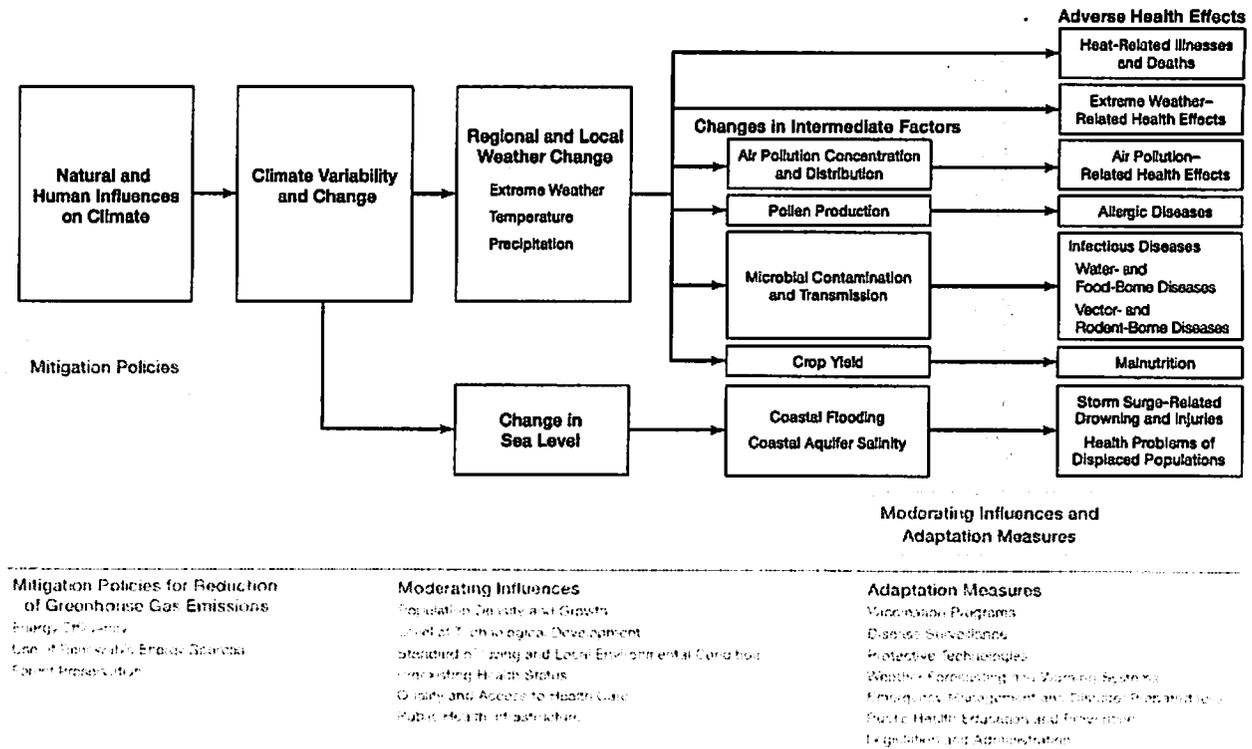
Climate change may contribute to the resurgence of malaria in areas where the public health infrastructure has broken down (eg, in central Asia and southern parts of the former Soviet Union). In regions where malaria has been locally eliminated but the vectors persist, there is a theoretical but small risk of localized outbreaks that could increase under climate change.

This is a topic of intense controversy and our understanding will continue to evolve as new research is conducted.

Dengue Fever and Other Arboviruses

The rate of dengue virus replication in *Aedes aegypti* mosquitoes increases directly with temperature in the laboratory. Biologically based models have been developed to explore the influence of

Figure. Potential Health Effects of Climate Variability and Change



Adapted from Patz et al.² Schematic of pathways through which climate change can affect multiple health outcomes. Examples are also given of moderating factors and adaptive measures determining extent of adverse outcomes, as well as mitigating measures to prevent global warming.

projected temperature change on the incidence of dengue fever. When linked to future climate change projections, such models suggest that relatively small increases in temperature in temperate regions, given viral introduction into a susceptible human population, should increase the potential for epidemics.²¹

Epidemics of certain arboviral (mosquito-borne) encephalitides, such as Saint Louis encephalitis virus, and West Nile virus may be influenced by climatic factors. Both have been associated with drought conditions²² and when West Nile virus appeared in the United States in the summer of 1999, the July temperatures in New York were the hottest on record. Outbreaks have also occurred in the Middle East and in eastern Europe following droughts.

Leishmaniasis

Leishmaniasis has become an important coinfection with human immunodeficiency virus in southern Europe and parts of Asia. There may be differences between vectors in susceptibility to climate change. For example, a study in Italy suggested that climate change could expand a range of one

vector but decrease the range of another.¹¹ Climate change could increase the geographical distribution of vectors in parts of Latin America and in southwest Asia.

Tick-Borne Diseases

There has been considerable interest in the potential impact of climate change on a number of tick-borne diseases, particularly Lyme disease, Rocky Mountain spotted fever, and tick-borne encephalitis. Temperature and humidity are important determinants of tick distribution. In Sweden, the extension of the northern limit of the distribution of the local tick vector²³ and increased cases have been attributed to milder winters. A statistical model of tick-borne encephalitis in Europe suggested that although disease foci could spread to higher latitudes and altitudes, the disease could largely disappear from central Europe because climate change would disrupt the complex life cycle of the tick.²⁴ However, land use change, in addition to the burgeoning deer population in the eastern United States, may be responsible for the increased risk of Lyme disease.²⁵

Rodent-Borne Diseases

The emergence of hantavirus pulmonary syndrome in the southwest United States in 1993 may be linked to drought followed by El Niño-driven heavy rainfall resulting in growth in rodent populations and subsequent disease transmission.²⁶ Extreme flooding or hurricanes can lead to outbreaks of leptospirosis. An epidemic of leptospirosis in Nicaragua followed heavy flooding in 1995. In a case-control study, a 15-fold risk of disease was associated with walking through flood waters.²⁷

Water-Related Diseases

Worldwide more than 1 billion people lack access to safe drinking water.²⁸ Modeling of impacts of climate change on water stress shows considerable variability between climate scenarios. Increased water stress is likely to occur in countries of southern and west Africa and in the Middle East. It is difficult however to relate this directly to the attributable risk of water-related diseases, although water scarcity may result in the use of more contaminated sources of fresh water because of combined use (same source for drinking, bathing, and irrigation). If in-

Table. Potential Range of Effects of Climate on Vector-Borne and Rodent-Borne Disease Transmission*

Climate Factor	Vector	Pathogen	Vertebrate Host and Rodents
Increases in temperature	Decreased survival (eg, <i>Culex tarsalis</i>) Change in susceptibility to some pathogens; seasonal effects Increased population growth Increased feeding rate to combat dehydration, therefore increased vector-human contact Expanded distribution seasonally and spatially	Increased rates of extrinsic incubation in vector Extended transmission season Expanded distribution	Warmer winters favor rodent survival
Decreases in precipitation	Increase in container-breeding mosquitoes because of increased water storage Increased abundance for vectors that breed in dried-up river beds Prolonged droughts could reduce or eliminate snail populations	No effect	Decreased food availability can reduce populations Rodents may be more likely to move into housing areas, increasing human contact
Increases in precipitation	Increased rain increases quality and quantity of larval habitat and vector population size Excess rain can eliminate habitat by flooding Increased humidity increases vector survival Persistent flooding may increase potential snail habitats downstream	Little evidence of direct effects Some data on humidity effect on malarial parasite development in Anopheline mosquito host	Increased food availability and population size
Increase in precipitation extremes	Heavy rainfall events can synchronize vector host-seeking and virus transmission	No effect	Risk of contamination of flood waters or runoff with pathogens from rodents or their excrement (eg, <i>Leptospira</i> from rat urine)
Sea-level rise	Coastal flooding affects vector abundance for mosquitoes that breed in brackish water (eg, <i>Anopheles subpictus</i> and <i>Anopheles sinclairi</i> malaria vectors in Asia)	No effect	No effect

*Adapted with permission from McMichael et al.¹¹

creased flooding in winter months in parts of the world is accompanied by increased drying in summer months, a double burden of water-related diseases may result in some countries. Outbreaks of cryptosporidiosis have been related to heavy rainfall events in the United States and elsewhere.²⁹

Warmer sea surface temperatures promote algal blooms that may be associated with cholera outbreaks. The incidence of cholera in Bangladesh in the earlier half of the last century (1893-1940) was uncorrelated with El Niño, although late in the century (1980-2001), the relationship was strong and consistent with strengthening El Niño events.³⁰

Malnutrition

According to the United Nations Food and Agriculture Organization, approximately 790 million people in developing countries are malnourished. Studies of the effects of climate change on food production suggest that yields of cereal grains are likely to increase at high and mid-latitudes but decrease at lower latitudes. In particular, there is concern that climate change may adversely affect nutrition in Africa mainly because of increased drought conditions.¹¹

Mitigating Climate Change

Mitigation refers to policies to reduce greenhouse gas emissions (eg, by promoting energy efficiency and the use of renewable energy sources such as solar and wind energy). This would especially apply to the United States, which produces more than 25% of global greenhouse emissions.³¹ Although discussion of greenhouse gas mitigation policy is beyond the scope of this article, medical personnel should recognize that reductions in greenhouse gas emissions will also likely provide near-term benefits via reductions in air pollution. The magnitude of the benefits will depend on the energy source that is being substituted (eg, the substitution of coal compared with natural gas as a fuel).

Conclusions

Physicians need to be aware of how current climate variability can affect health

outcomes. They should also recognize that long-term climate change may exacerbate climate-sensitive health problems. Early warning systems for heat waves may reduce impacts and ensure that elderly persons, particularly those who are socially isolated, are monitored, offered access to air conditioning, and given advice about fluid intake and appropriate clothing. Climate change may affect the distribution of a number of infectious diseases and emerging infections that should be considered in the diagnosis of patients with unexplained symptoms. Physicians can also educate communities about the potential impacts of climate change, the need to improve current public health infrastructure, and participate in policies to decrease dependence on fossil fuels.

Climate change poses a range of challenges to human health, but many of the linkages are complex and a range of other social, behavioral, and environmental factors also affect the health outcomes in question. Because of the wide-ranging potential impacts of global warming, a precautionary approach should be taken that seeks to decrease greenhouse gas emissions substantially, including the introduction of energy efficiency and renewable energy technologies.

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