

REVIEW ARTICLE

GLOBAL HEALTH

Globalization, Climate Change,
and Human Health

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THE GLOBAL SCALE, INTERCONNECTEDNESS, AND ECONOMIC INTENSITY of contemporary human activity are historically unprecedented,¹ as are many of the consequent environmental and social changes. These global changes fundamentally influence patterns of human health, international health care, and public health activities.² They constitute a syndrome, not a set of separate changes, that reflects the interrelated pressures, stresses, and tensions arising from an overly large world population, the pervasive and increasingly systemic environmental impact of many economic activities, urbanization, the spread of consumerism, and the widening gap between rich and poor both within and between countries.

In recent decades, international connectivity has increased on many fronts, including the flow of information, movements of people, trading patterns, the flow of capital, regulatory systems, and cultural diffusion. These exponential increases in demographic, economic, commercial, and environmental indexes have been labeled the Great Acceleration.³ Remarkably, the resultant environmental effects are now altering major components of the Earth system.^{4,5} The current geologic epoch is being called the Anthropocene (successor to the Holocene epoch)^{5,6} in recognition of the global force that *Homo sapiens* has become, pushing or distorting Earth's great natural global systems beyond boundaries considered to be safe for continued human social and biologic well-being.^{4,7} The loss of biodiversity, the greatly amplified global circulation of bioactive nitrogen compounds, and human-induced climate change have already reached levels that are apparently unsafe.⁴

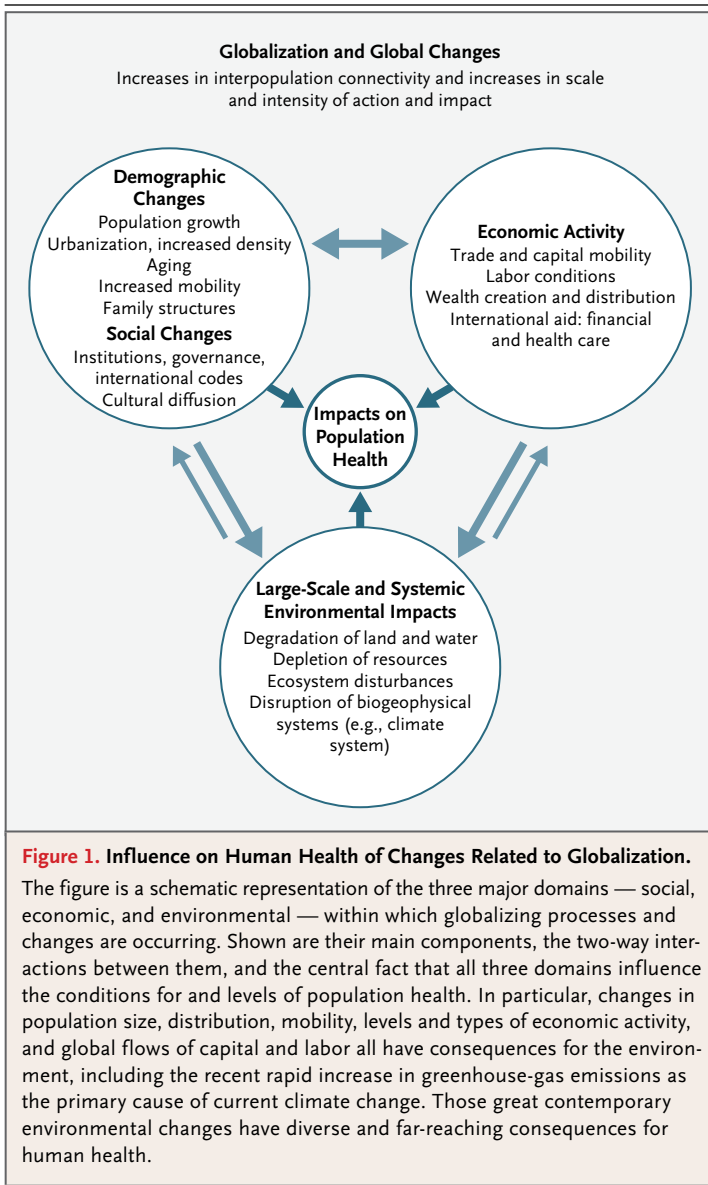
These changes pose fundamental threats to human well-being and health.^{4,7} For example, a positive relationship has been observed between regional trends in climate (rising temperatures and declining rainfall) and childhood stunting in Kenya since 1975, indicating that as projected warming and drying continue to occur along with population growth, food yields and nutritional health will be impaired.⁸ These human-induced climatic changes often act in concert with environmental, demographic, and social stressors that variously influence regional food yields, nutrition, and health. Furthermore, at the current level of global connectedness and interdependence, the environmental impact of human activity has a wider geographic range, although its influence may be offset somewhat by more effective global alerts and more rapid distribution of food aid. The extreme heat and wildfires in western Russia in the summer of 2010 destroyed one third of that country's wheat yield, and the subsequent ban on exported grain contributed to a rise in the price of wheat worldwide, exacerbating hunger in Russia (where flour prices increased by 20%) and in low-income urban populations in countries such as Pakistan and Egypt.^{9,10} On the economic front, the recent global financial crisis has underscored the domino-like interdependence of national economies.

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EFFECTS OF GLOBALIZATION ON POPULATION HEALTH

Global influences on population health such as those described above transcend the more specific, focused frame within which international health issues are addressed.² The processes of global change are more systemic, involving disruption or depletion (not merely local pollution). Remediating or adapting to these changes requires an understanding of dynamic systems, their complexity and associated uncertainties, and coordinated policy responses across relevant sectors. The relationships between these perva-

sive processes of change and human health are shown in Figure 1.

DEMOGRAPHIC CHANGES

Population growth is often overlooked in the discourse on global change, including its relation to the mitigation (abatement) of climate change, to which the contribution of global emissions is obvious.¹¹ The projections by the United Nations that today's population of 7 billion will increase to 9.3 billion by 2050¹² should reactivate the debate about whether we can succeed in pursuing realistic objectives for a healthy climate without curtailing the actual number of humans pressing on the environment. Furthermore, the negative-feedback loop of excessive population pressure on regional environments (involving soil exhaustion, water depletion, and the loss of various wild animal and plant food species) not only exacerbates various ongoing worldwide environmental and ecologic changes but also entrenches conditions of poverty and disadvantage. In these latter circumstances, fertility rates tend to remain high.

Some additional increase in the world population is inevitable in countries with high fertility rates, given the demographic flywheel momentum of populations weighted toward the young. Meanwhile, moderate gains have been made in facilitating education for girls, although progress in this, as well as in the provision of adequate education about reproduction and reproductive choice, remains slow in many low-income countries.¹³ Where unplanned pregnancy rates remain high (e.g., Timor-Leste and Nigeria), so do risks to maternal and child health.

SOCIAL CHANGES AND ECONOMIC ACTIVITY

Many other aspects of globalization influence population health,² including the accelerated emergence of new infectious diseases,^{14,15} the near-ubiquitous rise in the rates of obesity and associated noncommunicable diseases as daily bodily energy budgets (food energy input vs. physical energy output) shift into surplus,¹⁶ the spread of cigarette marketing, the effects of climate change,^{17,18} increases in resistance to antimicrobial agents, and health risks in the workplace due to the deregulation of international labor markets.² Looming large in the background as additional determinants of health are the persistent, even increasing, disparities in wealth, education, autonomy, and social inclusion.¹⁹ There are, of course, certain aspects of globalization

that are beneficial to health, such as the enhanced flow of information, improvements in internationally coordinated vaccination programs and systems to respond to infectious diseases, and a greater capacity for long-distance responses to disasters.

Adverse global influences on health, such as rising food prices and extended ranges of some infectious diseases, have also impeded attainment of the United Nations Millennium Development Goals.²⁰ Future global health goals must be better integrated with the fundamental influences of poverty, inequity, illiteracy, climate change, land-use patterns, and food insecurity on health. After the Rio+20 Conference (2012), the Millennium Development Goals are to be replaced by Sustainable Development Goals in 2016, reflecting the principle set forth at the original Rio Declaration on Environment and Development (1992) that concern for humans must be at the center of sustainable development. Nevertheless, concern for human health is not yet near that center. This reflects the continuing misperception of what health means and the dominance of a narrow, clinically based view that seemingly does not take into account the fundamental need, in improving population health, to address the poor fit between environmental and sociocultural conditions and basic human biologic and psychological needs.

ENVIRONMENTAL AND ECOLOGIC CHANGES

The deep-seated, essentially ecologic risks to population health cannot be countered effectively at the local level alone. Climate change induced by human activities, for example, is due to the globally aggregated excess of greenhouse emissions. Primary prevention of health problems arising from such global environmental and sociodemographic changes therefore requires coordinated international policy, supplemented by more local policy-making and action. For example, the World Trade Organization should give greater priority to averting the adverse health and environmental effects of international free trade.²¹ There is also a need for instruments similar to the WHO Framework Convention on Tobacco Control^{1,22} and the WHO Global Outbreak Alert and Response Network, in relation to the emergence of infectious diseases,²³ as well as the United Nations Environmental Programme Montreal Protocol to protect the ozone layer.²⁴

The following four examples describe other

environmental and ecologic changes on a global scale that will increasingly influence the world's health. First, the probability that new strains of influenza virus will emerge is increasing, particularly in the rural villages of Southeast Asia and East Asia.^{14,25} The risk increases with population growth; the juxtaposition of traditional backyard pig, chicken, and duck farming with intensified commercial poultry production; and environmental changes that affect the flight paths of migrating wild birds.

Second, the decline in available seafood protein (which is important for many low-income coastal populations) is a threat to health and reflects the unprecedented combination of ocean warming, acidification (due to increased uptake of carbon dioxide), deoxygenation,²⁶ destruction of coastal fish nurseries, and overfishing.²⁷

Third, diverse health risks are posed by the deprivation, displacement, and conflict that result from shortages of fresh water.^{8,28} Many populations, such as those in Bangladesh, Vietnam, Egypt, and Iraq, live downstream on great rivers that traverse several countries. In many cases, river flows are threatened by the loss of glacier mass and snowpack due to global warming and by the increased diversion of flow by neighbors upstream.

Finally, the need to maintain food supplies and adequate nutrition for the increasing world population presents a major challenge.²⁹ Global food production also faces pressures as a result of reduced yield due to land degradation, water shortages, and climate change and the rising demand for animal foods among middle-income populations. Furthermore, agriculture (especially livestock production) accounts for around one fourth of global greenhouse-gas emissions.³⁰ Thus, there are growing pressures to transform food production (e.g., more mixed cropping and inclusion of acceptable genetically modified crops), distribution, and consumption. Since the environmental, particularly climatic, effects of producing red meat from methane-producing ruminants (e.g., cattle, sheep, and goats) are so great, thought needs to be given to the question of whether production of this protein source will need to be curtailed — while allowing a sufficient increase to ensure safe childhood nutrition in the many poorer populations, which currently consume levels of red meat that are lower than those in the overconsuming rich populations by a factor of 10.³⁰ The global food security issue is

further complicated by the ongoing land grab in eastern Africa and elsewhere by richer countries seeking investment opportunities and self-insurance against future land, food, and biofuel shortages (e.g., Middle Eastern oil-producing states, China, and South Korea).³¹

These four examples also confirm that, in a world of global and systemic changes, these individual changes for the most part do not impinge on population health in isolation; instead, they typically act jointly and often interact. Specific examples are discussed in the next section, which reviews the health risks posed by climate change.

GLOBAL CLIMATE CHANGE

Global climate change is part of the larger Anthropocene syndrome of human-induced global environmental changes. These include land degradation, ocean acidification, and disruptions and depletions of the stratospheric ozone concentration, soil fertility, fresh-water resources, biodiversity stocks and ecosystem functioning, and global nitrogen and phosphorus cycles.⁴ Greenhouse emissions from fossil fuel–based power generation and transport and from the agriculture and mining sectors increase the heat-retaining capacity of the lower atmosphere, resulting in global warming (see the interactive graphic at NEJM.org). In addition, deforestation and ocean saturation have added to greenhouse warming by reducing the capacity of terrestrial and marine environments to absorb extra carbon dioxide (the main greenhouse gas) from the atmosphere. Also contributing to such warming are any ongoing natural variations in climate caused by cosmologic and geologic influences.³²



An interactive graphic showing global temperature trends is available at NEJM.org

Most of the global warming since 1950 (an increase of 0.7°C) has been the result of human activity.³² Annual global emissions of carbon dioxide have increased over the past decade, as have the rates of sea-level rise, the loss of Arctic sea ice, and the number of extreme weather events.³³ Without substantial and prompt international action to abate these emissions, average global temperatures (relative to the year 2000) are likely to rise by 1 to 2°C by 2050 and by 3 to 4°C by 2100, including increases of up to 6 to 7°C at high northern latitudes.^{33,34} Additional warming of another 0.7°C is locked in from the extra radiative energy already absorbed by the lower atmosphere and, in turn, by the oceans, though not yet manifested as surface warming. An average rise of 4°C would return Earth's temperature to a level not experienced for 10 million to 20 million years.³⁵

Rainfall patterns will also change, with rainfall increasing in some regions and seasons and decreasing in others. Modeling consistently projects an increase in regional aridity, and in the geographic range and severity of droughts, during this century.³⁶ The frequency, and perhaps intensity, of extreme weather events is also expected to increase in most regions — and may well have already begun to do so.³⁷

EFFECTS OF CLIMATE CHANGE ON HUMAN HEALTH

The complex nature of climate change and its environmental and social manifestations results in diverse risks to human health.^{17,18,38} A three-way classification of these risks and causal pathways is shown in Table 1.³⁹

Our current, rather skewed knowledge of climate–health relationships has come from epidemiologic studies of health risks in relation to differences and extremes in temperature and from quasicyclical climatic events such as the El Niño–Southern Oscillation phenomenon. However, most of the health risks will arise from climatic influences on environmental systems and social conditions that affect food yields, water supplies, the stability of infectious disease patterns, and the integrity of natural and human-built protection against natural disasters (including forest cover, windbreaks, mangroves, vulnerable constructed seawalls, and urban water-drainage systems) and from the adverse health consequences of social disruption, displacement of communities, and conflict situations.^{18,38}

Table 1. Categories of Climate-Change Risks to Health, According to Causal Pathway.

Risk Category	Causal Pathway
Primary	Direct biologic consequences of heat waves, extreme weather events, and temperature-enhanced levels of urban air pollutants
Secondary	Risks mediated by changes in biophysically and ecologically based processes and systems, particularly food yields, water flows, infectious-disease vectors, and (for zoonotic diseases) intermediate-host ecology
Tertiary	More diffuse effects (e.g., mental health problems in failing farm communities, displaced groups, disadvantaged indigenous and minority ethnic groups) Consequences of tension and conflict owing to climate change–related declines in basic resources (water, food, timber, living space)

Key examples of these types of causal paths are shown in Figure 2. Many of the indirect effects of climate change will be simultaneously influenced by other global changes and socio-demographic pressures that act in conjunction with climate change. Food yields and, hence, nutritional status reflect changes not only in

climate⁴⁰ but also in water supplies, soil fertility, nitrogen levels, biodiversity (e.g., pollinators and pest predators), and the health and vitality of farm workers.

It is not surprising that the health effects of climate change will be predominantly adverse.³⁸ After all, human biology, domesticated food

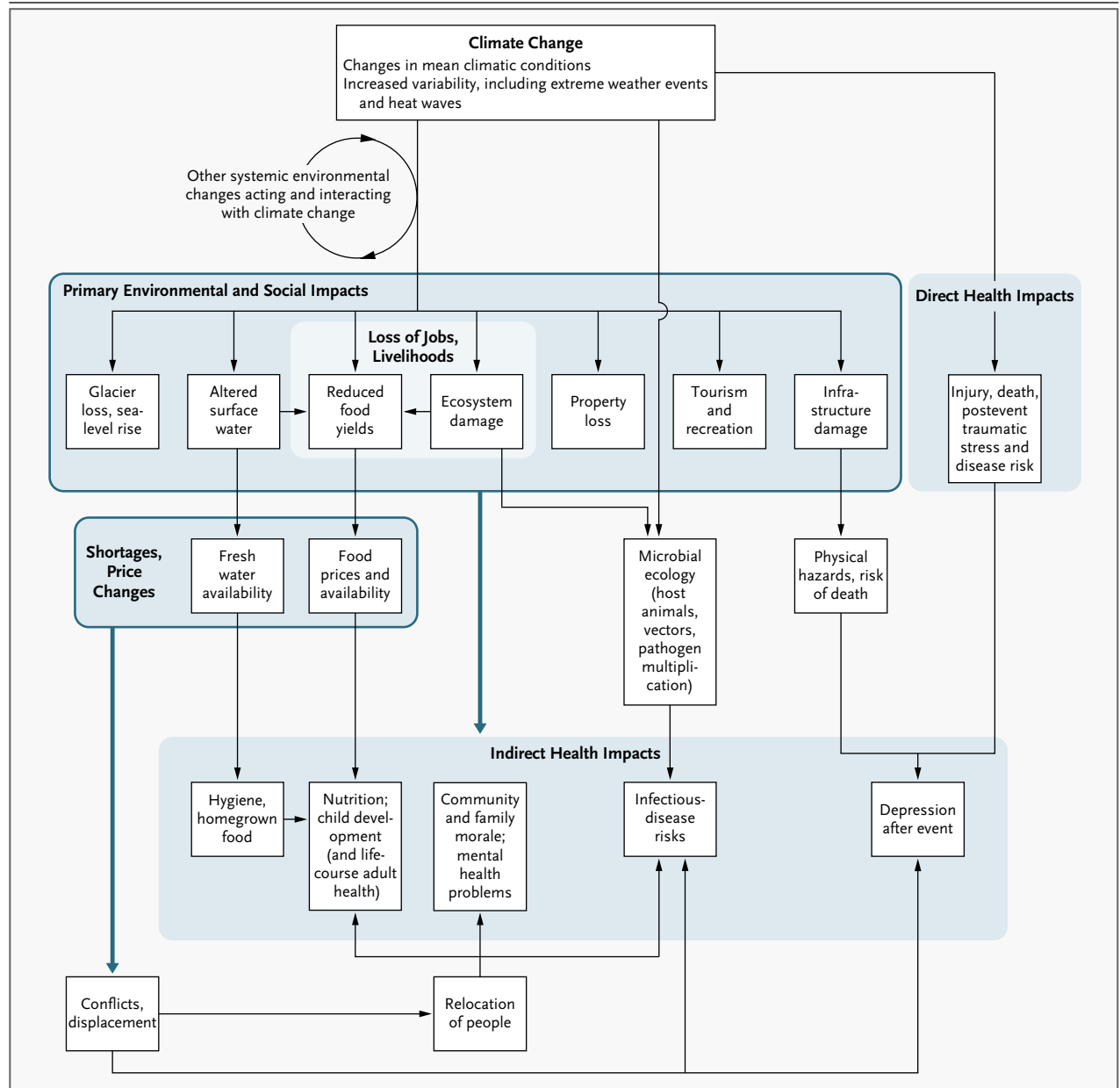


Figure 2. Processes and Pathways through Which Climate Change Influences Human Health.

The direct health impacts of climate change are shown in the upper right part of the figure, most of them due to amplified extreme weather events. All the other, less direct health impacts, shown in the lower part of the figure, are mediated by the primary environmental and social impacts of climate change. These include the five categories of indirect health impacts and the tertiary effects on health and survival that arise from more diffuse disruptions, dislocations, and conflicts, which are likely to increase in future decades and are indicated by upward-pointing arrows.

sources, and culture in general have evolved over many millennia within the usual prevailing climate. Furthermore, populations everywhere will be vulnerable to increasingly severe extreme weather events.

Some beneficial health effects are expected to occur, at least in the earlier stages of climate change.³⁸ In some temperate zones, milder winters may lead to fewer wintertime deaths from myocardial infarction and stroke, and in some low-latitude regions, hotter and drier conditions may reduce mosquito survival and, hence, mosquito-borne infection.

Populations living in diverse social, economic, and physical conditions will be affected differently by climate changes.^{18,38} Low-income and remote populations are more vulnerable to physical hazards, undernutrition, diarrheal and other infectious diseases, and the health consequences of displacement. Populations on low-lying islands and in coastal areas, such as Bangladesh, are vulnerable to increased storm surges and flooding as the sea level rises. In Arctic circumpolar regions, communities may undergo enforced changes in diet as land and marine animal populations migrate or decline and as access to traditional food sources becomes physically more difficult.⁴¹

The likely future effects of climate change on various health outcomes have been modeled with the use of plausible scenarios of future climate change that have been agreed on internationally. For example, in temperate countries, as summers become hotter and heat waves more severe, modeling indicates that, from around mid-century, additional heat-related deaths will progres-

sively overwhelm the number of deaths averted as a result of milder winters.^{42,43} Such estimates of the extreme effects of weather will improve as the modeling of changes in climatic variability under climate-change conditions improves and as researchers take better account of physiological, behavioral, and technological adaptation by populations over time.

In China, the modeling of medium-scenario warming indicates that the transmission zone of freshwater snail-mediated schistosomiasis will extend northward, putting another 20 million people at risk by 2050.⁴⁴ Such model-based estimation of the direction and approximate extent of likely change in health risks is an important resource for decision-making about both climate-change abatement and localized adaptation.

Meanwhile, an important research task is to identify ongoing changes in health risks and outcomes that can be reasonably attributed to recent climate change. Given the multivariate causation of most human health outcomes, attribution is rarely simple.⁴⁵ Nevertheless, over the past decade, observed changes in some health outcomes, viewed collectively, suggest a climate signal (Table 2).^{18,38,46}

HEALTH RISKS AND BENEFITS
OF CLIMATE-CHANGE MITIGATION
AND ADAPTATION

The mitigation of climate change is a crucial first-order task for the world. However, while governments continue to wrestle with this unprecedented, complex political and ethical task, the more immediate challenge for the health sector is to identify the main regional health threats posed by climate change and ensure the development of risk-lessening adaptations.

ADAPTATION STRATEGIES

Adaptation capacities and strategies will differ greatly among populations. They will be particularly important where the rates of preexisting disease (e.g., childhood diarrhea and malnutrition) are already high and therefore, in absolute terms, would become considerably higher because of the multiplier effects of climate change. Effective adaptive strategies will mostly require collaboration among diverse government sectors, research disciplines, and communities.

During heat waves, deaths and hospitalizations predominate among the elderly, patients

Table 2. Indicators of Early Health Effects of Climate Change.

Increases in annual numbers of deaths and hospitalizations due to extreme heat, observed in a range of high-income and low-income countries
Increases in rates of injuries and deaths due to the rising frequency of weather disasters in many regions
Extensions in the geographic range of several vector-borne infectious diseases or their vectors, including tick-borne encephalitis in Sweden, the tick vector of Lyme disease in eastern Canada, and malaria in the western Kenyan highlands
Although less certain, increases in the tempo of coastal outbreaks of cholera relative to the warming of coastal waters and El Niño events
Increases in the price of some staple foods, especially in vulnerable, food-insecure regions, leading to nutritional deprivation in low-income households

with chronic cardiorespiratory disease, and persons living in low-grade housing. Early heat wave–warning systems, community caregiver schemes for vulnerable persons, well-insulated housing, and educational advice from primary health care providers would lower this risk. Meanwhile, longer-term planning is needed to climate-proof urban residential areas.⁴⁷

HEALTH BENEFITS OF CLIMATE-CHANGE MITIGATION

One favorable aspect of efforts to mitigate climate change is that local health gains will quickly accrue to populations that undertake such efforts.⁴⁸ Awareness of this potential health dividend — in addition to the longer-term global health benefits — should strengthen support for such actions.

Health benefits will result from mitigating actions that address modes of transport, housing-design standards, energy generation, and agricultural systems (including livestock production). In many poor populations, improvements in

environment-related technologies will help to replace indoor-polluting cooking fuels with low-carbon fuels, and improvements in reproductive literacy will lead to fewer, better-spaced pregnancies; both types of improvement reduce pressures on the climate system.¹¹ All these actions will directly reduce well-known risk factors for disease and premature death (e.g., air pollution, sedentary living, and dietary excesses).⁴⁸ Innovative urban design can have wide-ranging positive effects with regard to energy use, greenhouse-gas emissions, the effects of urban heat islands, patterns of physical activity, social relations, and community cohesion.

CHALLENGES FOR THE HEALTH SECTOR

The health sector has important roles to play in relation to climate-change abatement and adaptation strategies for lessening unavoidable risks

Table 3. Role of the Health Sector in Climate-Change Mitigation (Primary Prevention) and Adaptation (Preparedness, or Secondary Prevention).*

Goal and Generic Action	Suggested Strategies
Mitigation of climate change	
Carry out health impact assessment of mitigation strategies	Conduct epidemiologic research to estimate and document changes in health outcomes that result directly from mitigation actions
Limit the carbon (and other environmental) footprint related to the health care system	Design buildings, transport services, and facilities to achieve energy efficiency, in terms of energy sources and use, and to minimize waste
Enlist health professional organizations and government health departments	Educate the public about risks to health from climate change and explain that mitigating actions can confer additional, local health benefits
Include physicians and other health care workers as citizens	Participate in wider public discussion and moderate personal behaviors
Adaptation to lessen health risks	
Provide adequate health care facilities and services	Improve facilities for handling increased patient volume resulting from extreme weather events and ensure adequate stocks of vaccine
Anticipate necessary surge capacity (e.g., for major heat waves, fires, epidemics)	Coordinate with emergency-services agencies and ambulance facilities and consider morgue capacity
Reinforce and extend public health programs to provide a foundation for dealing with most types of climate-related health effects	Develop early-warning systems (e.g., for heat waves, floods, and possible epidemics); programs for infectious-disease surveillance and analysis, vaccination, and vector control (e.g., mosquitoes, ticks); support for vulnerable communities; and mental health services (e.g., for postevent trauma and depression)
Educate and train the health workforce	Develop programs that prepare health care workers to contribute to public education and to be on the alert for unexpected diagnoses
Engage in broader collaboration with other sectors	Institute policies for creating green spaces in cities (to promote physical and mental health); develop housing design and insulation to optimize health protection; consider livestock and wild animals as possible risks for infection

* The listed adaptation activities are intended to reduce health risks on the local and regional levels.

to health (Table 3).^{49,50} Such strategies would include the “greening” of health care institutions and participation in national health impact assessments and in intersectoral planning of sustainable energy systems, transportation, and urban design. National delegations to international policymaking meetings that address global trends and threats (e.g., the annual conferences convened under the United Nations Framework Convention on Climate Change) should include representatives from, or at least substantive briefing by, the formal health sector.

CONCLUSIONS

Rapid globalization has brought new, large-scale influences to bear on patterns of human health. Various global-scale changes — economic, social, demographic, and environmental (particularly climatic) — are linked, for example, to the increased prevalence of obesity, changes in regional

food yields, the emergence of infectious diseases, the spread of cigarette smoking, and the persistence of health disparities.

Undertaking primary prevention at the source to reduce health risks resulting from these global influences is a formidable challenge. It requires conceptual insights beyond the conventional understanding of causation and prevention, as well as political will, trust, and resources. The complexities of policies to mitigate human-induced climate change are clear. Meanwhile, additional resources and strategies will be needed to reduce the health risks related to global change that have already arisen or are now unavoidable. For populations to live sustainably and with good long-term health, the health sector must work with other sectors in reshaping how human societies plan, build, move, produce, consume, share, and generate energy.

Disclosure forms provided by the author are available with the full text of this article at NEJM.org.

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