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GLOBAL ENVIRONMENTAL CHANGE AND HUMAN HEALTH

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The Earth's environment is showing signs of strain from a burgeoning world population and its impact on the planet's life support systems, creating headlines almost every day: increasingly crowded subsistence farming of pigs and poultry in southern China and Southeast Asia makes the emergence of new strains of avian influenza more likely, escalating the risk of new epidemics in humans. Climate change over the preceding three decades doubles the probability of severe heat waves in Western Europe, and in August 2003, a heat wave in Europe kills in excess of 30,000 people. Coastal deforestation and the clearing of mangrove forests exacerbate the impact of the 2004 tsunami in Asia. Poverty-driven patterns of human settlement in Central America multiply the damage to life, limb, and infrastructure caused by Hurricane Mitch and Hurricane Stan. The list goes on...

These amplifications of environmental impacts on human populations are facets of the ongoing, now dramatic, extension in both scale and type of the human impact on the natural environment, and the resultant risk to health. The sharp rise in human population in the 20th century, accompanied by energy and resource intensive economic development, has rendered this human impact so large and pervasive that it now entails perturbation of the Earth System itself (Andreae *et al.*, 2004; Steffen and Lambin, 2006). These disruptive changes to natural biogeophysical systems weaken Earth's life-support systems, and are referred to as Global Environmental Change (GEC). In this paper, we will use the term GEC to represent the biological, chemical, and geophysical aspects of Global Change, i.e., the pervasive change in the Earth System that also includes the social, economic and political aspects (Steffen *et al.*, 2004b).

1. Global Environmental Changes

The best known component of GEC is global climate change, which, like stratospheric ozone depletion, affects the entire planet. Diverse sources of greenhouse gases (GHG) around the world – power-generating plants, factories, vehicles, wet farmlands, deforested areas, and others – change the composition and, hence, the heat-trapping properties of the lower atmosphere. The resultant change in climate occurs at a global scale, affecting populations everywhere, notwithstanding the many original local sources of the gaseous emissions. One of the great problems that stands in the way of finding a course of action to mitigate climate change is just this disconnect between local cause and effect. Because it is only the integrated effect of a vast number of local emissions that results in climate change, it becomes difficult for individuals and policymakers to associate their actions (emissions) with their consequences (climate change). In fact, it appears that the populations most vulnerable to human-induced climate change are not those that cause most of the GHG emissions, but people in the developing world who contribute minimally to the atmospheric burden of these gases (Shah *et al.*, 2006).

Along with these globally integrated atmospheric changes, human actions are also causing marked changes in the local, regional, and global cycles of nitrogen and phosphorus, and have initiated the global dissemination (especially to higher, non-industrial, latitudes) of semi-volatile persistent organic chemical pollutants (POPs). Various other worldwide environmental changes also reflect the escalating extent and intensity of human pressure on the global environment. These include disruptions to ecosystems, land degradation, biodiversity losses, depletion of freshwater resources, and critical pressures on ocean fisheries (Schellnhuber *et al.*, 2004; Dobson, 2006; Meybeck, 2006).

The complexity and scale of these various GECs, which often entail changes to ecological and geophysical processes, make the identification and quantification of the resultant health risks difficult. This paper explores the relationships between various types of global change, their social, demographic and economic drivers, and their impacts on population health. It suggests some areas for future research, and proposes policy guidelines for the achievement of sustainable development and, hence, the reduction in risks (present and future) to human health that result from existing practices.

While awareness of the processes of globalization and global environmental change has increased in recent years, there has been insufficient attention paid to the interconnectedness and likely consequences of these processes. These large-scale changes represent a new dimension to the state of the world in which we live – an era now referred to by some as the Anthropocene, due to the overwhelming dominance and influence of the human species (Steffen and Lambin, 2006). The changes reflect the continued expansion of the human population, the magnitude and growing intensity of economic activity (including escalating levels of consumption and waste generation), and the associated impacts on social structures, wealth distribution, geopolitical relations, and environmental systems and resources.

Much of the recent discourse on 'sustainability' has focused on whether humans can maintain current levels of social and economic activity without depleting the natural environmental resource base. There has been little recognition of the risks that GEC pose to the health, perhaps even survival, of human populations, both present and future. Yet (viewed anthropocentrically) the reason for seeking to optimize social structures, environmental integrity and economic productivity is essentially to improve human well-being, health and survival. We ought, then, to recalibrate our discussion of 'sustainability' to take explicitly into account the implications of global environmental changes for human health.

2. Drivers of Social and Environmental Changes, Interactions, and Health Impacts

The continuing global population growth (Lutz, 2006), increasing levels of material wealth and consumption, prevailing technologies, and aspects of globalization (increases in human inter-connectivity – economic, physical, cultural, microbial, electronic, etc.) are the fundamental drivers of these environmental changes. Over recent decades neo-liberal market-driven economic policies, with reduced governmental controls on industrial pollution, have amplified these environmental pressures further. Meanwhile, these underlying large-scale drivers are also having increasingly pervasive effects on social, economic and political conditions around the world.

Much attention has been paid to how urbanization, social change, trade liberalization, and environmental change affect outcomes such as social relations and community cohesion, economic development, levels of poverty, air quality, and food production and distribution. Less attention has been paid to how these changes affect human population health. Yet, the trend in human health, observed over decadal time, is clearly a key indicator of whether society at large has achieved a sustainable way of managing the natural and social environments (McMichael, 2002; Huynen and Martens, 2006). The huge disparity in economic wealth across nations, and the resultant inequitable distribution of public health status can be visualized in the form of 'cartograms' (Gastner and Newman, 2004), where countries are drawn in a size proportional to population, gross domestic product (GDP), and child mortality (Figure 1, see page 420).

Over the short term, material conditions have improved in most populations, and average life expectancy has continued to rise. However, over the past decade, life expectancy has decreased in a dozen or more countries (McMichael *et al.*, 2004); infectious diseases seem to have become more labile in distribution, resurgence, and emergence (Morens *et al.*, 2004; Weiss and McMichael, 2004; McMichael, 2006); and the total number of malnourished persons in the world has risen slightly over the past half-decade, after declining during the 1990s (FAO, 2005). Meanwhile, there are rising concerns about recent trends in many material environmental indicators – freshwater availability, urban air quality, supplies of energy (the 'peak oil' debate), and the prospects for continuing to feed the world population on the basis of sustainable production methods.

Figure 2 provides a simple representation of how the various major components of 'global change' – encompassing changes in demographic patterns, social-cultural relations, the economy, technology, and the environment – affect population health. The interactions between these components are also shown.

A fuller model would incorporate the ways in which the health subsystem may feed back into the socioeconomic subsystem and ultimately into GEC. The interconnected components of global change, with the added dimension of health feedback, are shown conceptually in Figure 3.

The implications of population health deficits for economic productivity and, in turn, socio-economic development have recently been examined in detail (Bloom and Canning, 2000; Commission on Macroeconomics and Health, 2001; Sachs and Malaney, 2002). The unabated burden of malaria in Africa has been calculated to have halved the growth rate of income per capita during 1965 through 1990 (Gallup and Sachs, 2001). In China, air pollution takes a high toll on human health and thereby also causes large economic costs (Brajer and Mead, 2004). Finally, the extreme example of the ballooning impact of HIV/AIDS in Sub-Saharan Africa on economic

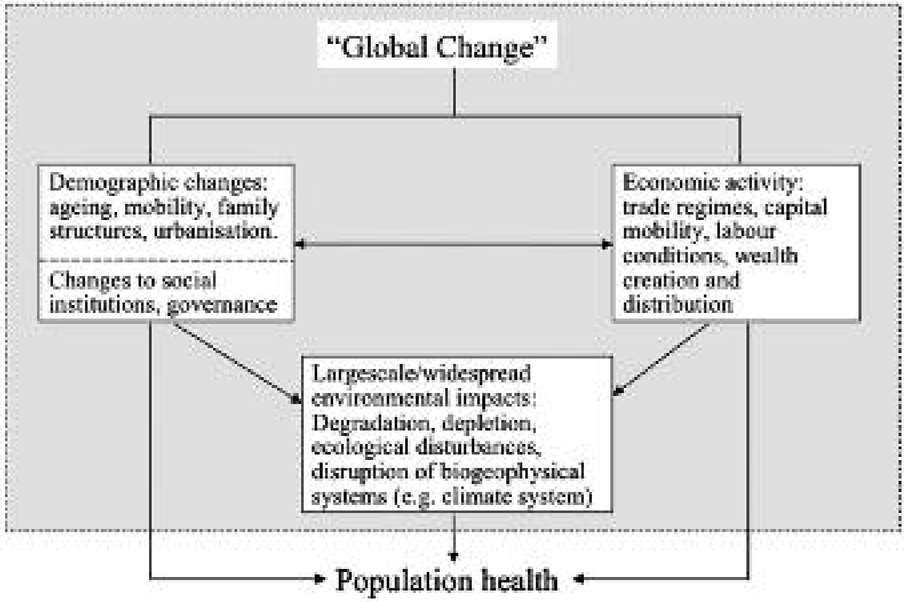

Figure 2. Schematic representation of the main components of 'global change' (comprising the area shown against shaded background), and the paths by which they affect human health and disease.

Figure 3. Relationships between socioeconomic conditions, environmental changes, and human health, showing the complexity of this system.

productivity, as the ranks of teachers, farmers, health workers, and others are depleted, is now well known (Piot *et al.*, 2001). The initial impact may be of an arithmetic kind, but the future impact may increase exponentially due to the erosion of social, educational and cultural institutions.

While poor population health can impair society's overall economic advance, the typically uneven distribution of poor health within the population often exacerbates poverty. Poverty, especially in combination with population, increases the pressure on the natural environment. These interactive relationships have recently been examined in detail by the Millennium Ecosystem Assessment (Hassan *et al.*, 2005).

Ultimately, the outcome of the interactive processes between human society, ecosystems and climate will depend on the resilience of social and economic systems, ecosystems, and climate (Butler *et al.*, 2005; Carmichael, 2006; Huynen and Martens, 2006; Jäger, 2006). Limited health effects and ecosystem disruptions, coupled with appropriate social responses, can be accommodated in scenarios where population health improves in both poor and wealthy populations. On the other hand, a combination of degraded ecosystem services and poor governance could lead to 'system failure' with dramatic harm to human health and well-being, precipitating further collapse of social and economic systems (Butler *et al.*, 2005). This, in turn, can be expected to have major consequences for climate scenarios. The highly coupled character of the system depicted in Figures 2 and 3 implies the probability of strongly non-linear responses, including abrupt 'state transitions', as we enter previously unexplored regimes of the Earth System as a consequence of human perturbations (Steffen *et al.*, 2004a; Steffen and Lambin, 2006).

3. Effects of Global Environmental Changes on Human Health

The escalating levels of environmental change are having observable effects on many plant and animal species (Houghton *et al.*, 2001; Hassan *et al.*, 2005). For example, global climate change over the past quarter-century has affected the seasonal cycles, geographic distribution, numbers, and, in some cases, survival of plant and animal species (Parmesan and Yohe, 2003; Root *et al.*, 2003). In some cases, e.g., extinctions of amphibians from infectious disease, a clear connection between climate change and animal disease has been identified (Pounds *et al.*, 2006). In human populations, however, patterns of health and disease are affected by many social, environmental, behavioral, health-care and other factors. Hence, the attributable impacts of GEC on human health are less clear-cut than in non-human systems. Still, a recent assessment by the World Health Organization (WHO) has estimated that the climate change which has occurred by the year 2000 (about 0.7°C over the last 100 years) is already responsible for over 150,000 deaths and ca. 5 million 'disability-adjusted life years' per year (Figure 4, see page 421) (World Health Organization, 2002).

Changes in the environment affect human health via diverse pathways. This is well illustrated by the diverse ways in which regional climate change and land-use change affect infectious disease patterns (Foley *et al.*, 2005; Patz *et al.*, 2005; Confalonieri *et al.*, 2006; Heymann, 2006; McMichael, 2006). Global patterns of parasitic and infectious disease species diversity show close connections to climate and total species diversity, with maxima in tropical regions (Guernier *et al.*, 2004). Changes in biological and ecological relationships often modify the distribution and behavior of vector species and intermediate host species, thereby altering the transmission of infectious disease (Dobson, 2006). Examples include changes in the patterns of tick-borne encephalitis in Sweden and Lyme disease in the northeastern United States, and the emergence of Nipah virus disease in humans as a result of the combination of intensified pig-farming, increasing deforestation, and altered ecology in Malaysia (Lindgren *et al.*, 2000; Ostfeld and Keesing, 2000; Harvell *et al.*, 2002; Weiss and McMichael, 2004; Olival and Daszak, 2005; Eaton *et al.*, 2006).

The rate of entry of microbes, both novel and previously encountered, into human populations is increased both where high human-population densities are in close contact with animal reservoirs of infectious disease, and where food production methods have been intensified (Weiss and McMichael, 2004). Pathogens can be exchanged between domestic and free-living wild animals in both directions, and can be passed to humans from both domestic and wild animals. This transfer of pathogenic microbes between animals and humans, and the resulting potential for emerging infectious diseases, poses a serious threat to human health (Daszak *et al.*, 2000; Wolfe *et al.*, 2005).

Meanwhile, malnutrition – which remains widespread in many developing countries and is sometimes exacerbated by environmental changes including land degradation, fisheries depletion, and climatic extremes – creates large immune-compromised populations into which infectious diseases spread more easily.

Global environmental changes also affect the occurrence of non-infectious diseases and the risk of physical injury and death. A very important example is that of malnutrition and associated disorders as a result of the combined stresses on agricultural yields from various forms of environmental change – including land degradation, freshwater shortages, climate change, and altered patterns of plant pests and diseases (Gregory *et al.*, 2005; Meybeck, 2006). Models that forecast the effect of climate change on agricultural yields over coming decades indicate a pattern of gains in developed countries and declines in developing countries, where food production is often already insufficient. According to the WHO, about 800 million people are presently undernourished, with almost half of them living in Africa (World Health Organization, 2002). The anticipated nutrition declines in the developing world would further exacerbate malnutrition and the risk of famine (Shah *et al.*, 2006).

The risk of injuries and deaths increases during extreme weather events (floods, hurricanes, etc.) and very hot weather (McMichael *et al.*, 2006). Extreme events, such as the European heat wave of 2003, which caused 22,000-45,000 excess deaths during a two-week period (Patz *et al.*, 2005), are expected to increase during the 21st century as the average temperature of the Earth increases and climatic patterns become more variable (Stott *et al.*, 2004).

The warming effect of anthropogenic GHG has been offset partly by the net cooling effect of atmospheric aerosol particles, which are released primarily by burning fossil fuel and biomass (Houghton *et al.*, 2001; Andreae *et al.*, 2005). Aerosols also affect the behavior of clouds and thereby the formation of rainfall, with as yet unknown consequences for water supply in susceptible regions. Aerosol particles also cause diverse adverse health effects, contributing to both non-infectious and infectious diseases, with resultant global excess mortalities in the millions annually (Pope *et al.*, 2002; Smith and Mehta, 2003; Schwartz, 2004). It has recently been estimated that exposure to aerosol pollution reduces the average life expectancy by 8.1 months in the 25 EU countries, reaching as high as 13.2 months in Belgium (Amann *et al.*, 2005). Aerosol pollution is not limited to industrialized areas, and now covers vast regions of the world, particularly in Asia and other developing regions. The resulting regional haze from anthropogenic aerosols also reduces solar radiation and thereby reduces crop yields, promoting malnutrition and associated health risks (Chameides *et al.*, 1999). The future dilemma, discussed below, is that a reduction in aerosol pollution will also accelerate global warming.

From a socio-economic perspective, the ecology of modern urban living has changed the calculus of benefits and risks to health. One example, now being widely discussed, is the surge in prevalence of obesity in many countries, especially in urban populations. This population-level phenomenon reflects the ready access of a community to energy-dense foods and to a pattern of daily living with diminished need for physical activity. This surge in obesity is occurring especially (and without precedent) among children and teenagers; it will result in a rise in the incidence of serious adult diseases (diabetes, cardiovascular disease, and others) and, very likely, a decrement in that generation's average life expectancy (Olshansky *et al.*, 2005).

4. Effects of Changes in Population Health on the Environment

In the previous section, we have discussed how environmental changes affect human health. Influences in the opposite direction, i.e., the effects of changes in population health on the global environment and climate, are less obvious and less well understood. Yet, there is evidence for important, though indirect, causal connections that link environmental change to population health and growth. Historical analysis of the growth of the human population, from prehistory to the present, indicates that agricultural expansion and deforestation has resulted in increases in atmospheric CO_2 and methane. Conversely, massive pandemics, such as the one that followed European colonization of the Americas and the resulting introduction of infectious diseases, have led to regrowth of forests and a concomitant drop in atmospheric carbon dioxide concentration (Ruddiman, 2003; Ruddiman and Carmichael, 2006).

Looking from the past into the future, we see that policies intended to improve human health by tightening aerosol emission regulations may have negative climate effects. As discussed in the previous section, the growing awareness that aerosols impair human health results in increasing pressure for regulations limiting aerosol emissions. These regulations, however, would also eliminate the aerosol's cooling effect on climate. As a consequence, greenhouse-induced climate change may actually accelerate as a result of policy decisions on aerosols that are primarily motivated by public-health concerns. Much preferable would be a balanced policy that incorporates the parallel reduction of both greenhouse gas and aerosol emissions (Andreae *et al.*, 2005).

At the most fundamental level, the pervasive improvement in public health in the 19th and 20th centuries has ultimately made possible the massive global change that the world is experiencing at present. Improvements in health care, urban sanitation, domestic hygiene, nutrition, and literacy have resulted in greatly reduced infant/child mortality and have facilitated rapid growth in the human population. By reducing costs associated with mortality and disease, they have also allowed increasing accumulation of wealth in the hands of individuals, enabling the development of a consumer society. This, together with an increasingly energy-intensive and carbon-intensive economy over the past century, has caused the rapid build-up of anthropogenic greenhouse gases in Earth's atmosphere.

The underlying relationship between demographic and economic changes and environmental impacts was originally expressed by Ehrlich and Holdren in the form of the 'IPAT Equation' (Ehrlich and Holdren, 1971). Although this simple equation cannot adequately express the complexities of interactions between humans and the environment (and makes no explicit reference to 'health'), it illustrates the fundamental quantitative relationship between population size and vigor, human economic activities, and environmental impact (Chertow, 2001).

IPAT is an identity stating that environmental impact (I) is the product of human population size (P), level of affluence (A), and type of technology (T):

$$I = P \cdot A \cdot T$$

In the context of CO_2-driven climate change, this equation is reformulated as:

Carbon emission = Population * (Unit GDP/capita) * [(Unit CO_2)/(Unit Energy) * (Unit Energy)/(Unit GDP)]

Although human population health is not present explicitly in the IPAT identity, its indirect influence via socioeconomic effects is quite profound (see also Figure 2). Health effects are parameterized in two terms of this equation. First, it is implicit in the population term, since public health acts directly on demographic structure and population size. Second, because of the connection between health and wealth (Bloom and Canning, 2006), the second term, per capita GDP, is also an implicit function of population health. Ultimately, the complex processes hiding behind the simple conceptual relationship reflected in the IPAT identity will have to be implemented explicitly in Earth System models.

5. Research and Surveillance: Indicators, Scenarios, Modeling

A prime research task is to elucidate further the fundamental relationships between environmental change, socio-economic processes, and population health. For this protean research task, suitable population-level indicators of human well-being and health are needed. However, few such indicators exist.

Mortality, for which data are plentiful (albeit often incomplete from poorer countries), is often an unsatisfactory measure of health and well-being. Life expectancy, while being a better metric, is often dominated by early-age deaths; furthermore, it does not shed light directly on sickness, disability, and overall well-being. More useful and better-integrated indicators of health and well-being are needed, along with indicators of vulnerability.

These would incorporate information about where people live (geographical conditions), resource availability (nutrition, water, energy), socio-economic conditions (including institutions that support and protect people), health status (life expectancy, disability, disease incidence), as well as people's perceptions about their living conditions (Heymann, 2006; Jäger, 2006).

The relationships between environment, socio-economic conditions, and health now extend across an unprecedentedly large span of time and space. The climate change process, in particular, spans decades, perhaps centuries. Hence, many of the health consequences of today's actions and their environmental impacts will only be realized well into the future. Once set in motion, however, these slow but massive environmental changes are not easily reversed. Some effects, such as biodiversity losses, ecosystem collapse and topsoil loss, are irreversible on human time scales.

This unfamiliar situation, unprecedented in human experience but now gathering momentum at an increasingly global scale, requires the development of research and evaluation tools to 'look into the future' – i.e., Earth System models that incorporate the interactions between climate and the human dimension, including health (McMichael, 2006). In the simplest case, population health can be part of economic and population submodels, the results of which can be used as input scenarios for climate system models. In contrast to the very simplistic scenarios used today as input to climate projections (Nakicenovic and Swart, 2000), they should include potential future risks (e.g., pandemics, famine, migration, and conflict) (Huynen and Martens, 2006). The climate projections so obtained can then be used as forcings for socioeconomic models.

This approach is only valid, however, as long as climate feedbacks on the socioeconomic part of the Earth System are weak compared to forcings inside the human subsystem. If, however, these feedbacks turn out to be strong, fully coupled models would be required, a challenge that goes way beyond what is possible today. These models will have to be developed, probably using EMICs (Earth System Models of Intermediate Complexity) as an initial step, and then tested with environmental, socioeconomic, and health data. They can then be applied to look for future hazards to the well-being of humanity and the environment, and to explore paths to sustainable development. While these complex models are being developed, progress can be made with simplified approaches to connect health and climate, e.g., in relation to climate change and future patterns of transmissibility of mosquito-borne infections, such as dengue fever (Hales *et al.*, 2002).

6. Policy Recommendations

Although much new research is needed to elucidate these complex contemporary environmental problems, some policy guidelines can already be identified. These include:

– Recognition of the fundamental significance of population health within the 'sustainability' policy framework

– Inter-governmental commitment to change and cooperation, with the goal of reducing the rate and magnitude of GEC

– An understanding that shifts to new technologies, which create more economic and social advantage than disadvantage

– Particular commitment to economic and related policies that reduce material inequalities and, hence, vulnerabilities

– Improvements in international systems of infectious disease surveillance and control

– New, bold, forms of interdisciplinary research – essential to the tackling of complex environmental-change phenomena and their social, cultural and political remediation.

Sustainable development is, in the long run, defined by its capacity to sustain human health and well-being. It is characterized by environmental practices that maintain the integrity and productivity of natural and managed ecosystems, a healthy economy, full employment, comfortable material living standards, efficient social security and assistance, good educational systems, adequate public infrastructure, and political freedom and stability (Carmichael, 2006; Jäger, 2006). Attaining these population health-promoting conditions will demand technologies, community behaviors and inter-governmental agreements that conserve the ability of the world's natural environment to support human life (Jäger, 2006).

This collective, global, task will require shared insight, commitment, resources, and political will among nations. The improvement of social, economic, and environmental conditions is inherent to attainment of the eight U.N. Millennium Development Goals, which range from halving extreme poverty to halting the spread of HIV/AIDS and providing universal primary education, all by the target date of 2015 (United Nations, 2005). Further, because the adverse impacts of environmental change (such as a reduction of agricultural yield) are most likely to occur in already disadvantaged regions, an emphasis on achieving greater international social and economic equality is essential (Jäger, 2006; Sachs, 2006). This includes the immediate need to fund ongoing programs to contain or eradicate infectious diseases, such as polio, and to reduce other major scourges such as malaria, tuberculosis, HIV/AIDS, and child diarrhea. These take a huge toll on human life, especially in developing countries (Heymann, 2006).

A key requirement in operational efforts to prevent and limit health losses, especially infectious disease epidemics and pandemics, is the availability of coordinated international surveillance and effective early-warning systems (Heymann, 2006; Jäger, 2006). The recent experiences of severe acute respiratory syndrome (SARS) and avian influenza, as unexpected causes of human infection and death, underscore this need. The existing regional infectious disease surveillance systems should be upgraded and put to optimal use within a better-coordinated international framework. To predict the spread of disease once it has been detected by such surveillance systems, improved spread models are required that take into account the complex patterns of biological, social, and spatial factors involved (Ferguson *et al.*, 2003; Hufnagel *et al.*, 2004; Brockmann *et al.*, 2006). Given effective early warning systems and a strategy for prompt intervention, it may be possible to contain emergent pandemics before they can cause massive damage to human health and world economics (Ferguson *et al.*, 2005; Longini *et al.*, 2005) – or at least postpone the emergence of a pandemic (Mills *et al.*, 2006).

Meanwhile, gains in wealth must be accompanied by measures to reduce the longer-term environmental consequences of increases in population size, affluence and consumption (Jäger, 2006). Energy-inefficient, high-throughput, waste-generating economies must be reoriented towards low environmental impact and the recycling of materials. Industrial and commercial activity that depends on throw-away items generates enormous emissions and other wastes that contribute to environmental degradation and its risks to health.

Emissions of greenhouse gases and atmospheric aerosols offer one complex example of how human-health risks must be taken into account alongside consideration of environmental consequences *per se*. Health-motivated reductions in aerosol emissions without simultaneous cuts in CO_2 output, as would be achieved for instance by stack scrubbing technology, would improve health but also increase global warming, because the cooling effect of the aerosols would be reduced. Aerosol emission cuts must therefore be accompanied by accelerated reduction of greenhouse gas emissions, particularly CO_2 (Andreae *et al.*, 2005). A special case is black carbon aerosol, emitted particularly from diesel engines. Reduction of black carbon emissions, which in contrast to other aerosol types has a warming effect on climate, would simultaneously cut back on climate change and improve health (Hansen and Nazarenko, 2004). This illustrates the type of 'win-win' solutions that are often possible. Co-benefits are also obtained from measures to reduce CO_2 emissions, because they always lead to simultaneous reductions in the release of SO_2, NO_x, and other pollutants, with associated health and socio-economic benefits (Aunan *et al.*, 2004; van Vuuren *et al.*, 2006).

Finally, our incomplete scientific understanding of the complex relationships discussed in this paper must be advanced. This requires the integration of research in the natural sciences and the health sciences with that of the humanities and social-economic sciences (McMichael *et al.*, 2003; McMichael, 2006). Conceptual gaps between these disciplines must be bridged, and the techniques of research and analysis made compatible among disciplines. A start in this direction has been made by the Earth System Science Partnership, a joint activity of the current global change programs in climate change (World Climate Research Programme), geosphere/biosphere interactions (International Geosphere/Biosphere Programme), biodiversity (Diversitas), and human dimensions (International Human Dimensions Program).

The increased engagement of researchers in this domain will add a crucial dimension to the evolving policy debate about climate change and other large-scale environmental changes. Good interdisciplinary research will clarify the extent to which the impacts of those changes include potentially serious health/survival consequences for human communities. This will extend the policy discourse beyond independent consideration of economic disturbance, loss of environmental amenity, threats to species, and risks to built infrastructure. It will thus help us understand better the real meaning and prerequisites of 'sustainability'.

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