

Public health

The changing global context of public health

A J McMichael, R Beaglehole

Future health prospects depend increasingly on globalisation processes and on the impact of global environmental change. Economic globalisation—entailing deregulated trade and investment—is a mixed blessing for health. Economic growth and the dissemination of technologies have widely enhanced life expectancy. However, aspects of globalisation are jeopardising health by eroding social and environmental conditions, exacerbating the rich-poor gap, and disseminating consumerism. Global environmental changes reflect the growth of populations and the intensity of economic activity. These changes include altered composition of the atmosphere, land degradation, depletion of terrestrial aquifers and ocean fisheries, and loss of biodiversity. This weakening of life-supporting systems poses health risks. Contemporary public health must therefore encompass the interrelated tasks of reducing social and health inequalities and achieving health-sustaining environments.

We are living through what is, historically, a major transition in the health of populations. There have been broad gains in life expectancy during the past half-century. Fertility rates are declining. The profile of major causes of death and disease is being transformed; the pattern of infectious diseases has become much more labile (and antimicrobial resistance is rising widely); and health inequalities between rich and poor persist. Today, the prospects for future health depend to an increasing—but as yet uncertain—extent on the processes of globalisation and on the emergence of global environmental changes occurring in response to the great weight of man's economic activity. We are at a substantive, not merely a millennial, crossroads.¹ We describe the changing context within which public-health researchers and practitioners must address both traditional and new challenges to population health.

Improvements in the health profile of western populations during the past two centuries have resulted primarily from broad-based changes in the social, dietary, and material environment, shaped in part by improved sanitation and other deliberate public-health interventions. In less-developed countries, health gains have begun more recently in the wake of increased literacy, family spacing, improved nutrition, and vector control, assisted by the transfer of knowledge about sanitation, vaccination, and treatment of infectious diseases.² These observations remind us that public-health researchers and practitioners, and those in the political and public realms with whom they interact, must take a broad view of the determinants and, indeed, the sustainability of population health. This is an ecological view of health; an awareness that shifts in the ecology of human living, in relation to both the natural and social environments which account for much of the ebb and flow of diseases over time.

What then is to be the scope of “public health”? Broadly defined, public health is “the art and science of preventing disease, promoting health, and extending life through the organised efforts of society”.³ There is today a growing

recognition of the importance of two fundamental dimensions to this public-health task. First, because social and material inequalities within a society generate health inequalities, an important task is to elucidate, through research, the underlying determinants of these health inequalities.⁴ That knowledge must then be applied, in part through professional practice, to the development of ameliorative social policies. Public health, as Virchow pointed out more than a century ago, is “politics writ large”. Second, longer-term changes in the structure and conditions of both the social and natural environments will affect the sustainability of good health within populations. The dearth of social capital and the associated failure of public institutions in Russia and its neighbours following the collapse of communism potentiated the widespread decline in population health indicators in the early 1990s.^{5,6} The advent of human-induced global environmental change—especially global climate change, depletion of freshwater supplies, loss of biodiversity, and the degradation of managed ecosystems (especially arable lands)—jeopardises the life-supporting capacity of the biosphere.^{7,8}

The scope of contemporary public-health analysis must, therefore, encompass those two larger-scale dimensions: the reduction of social and health inequalities and the striving for health-sustaining environments. In traditional, largely self-contained, agrarian-based societies that produce, consume, and trade on a local basis and with low-impact technologies, the social and environmental determinants of health are predominantly local. However, the industrialisation and modernisation of the past century has altered the scale of contact, influence and exchange between societies, institutionalised hierarchical economic relations, and has exacerbated the rich-poor gap worldwide and increased the scale of human impact on the environment.

An important step towards addressing these two dimensions has been the recent affirmation that a population's health reflects more than a simple aggregation of the risk-factor profile and health status of its individual members. It is also a collective characteristic that reflects the population's social history and its cultural, material, and ecological circumstances.⁹⁻¹¹ Epidemiological analysis that is confined to studying “risk factor” differences between individuals gives little insight into variations in population health indices, either between populations or over time. For example, the effect on mortality of heatwaves and cold spells differs between European populations at low and high latitudes, reflecting differences in culture, housing design,

Lancet 2000; **356**: 495–99

Department of Epidemiology and Population Health, London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT, UK (Prof A J McMichael MBBS); and Department of Community Health, Faculty of Medicine and Health Science, University of Auckland, Auckland, New Zealand.

(Prof R Beaglehole DSc)

Correspondence to: Prof A J McMichael (e-mail: t.mcmichael@LSHTM.ac.uk)

and environmental conditioning.¹² The inverse relationship seen in populations of more-developed countries between within-population income gradient and average life expectancy¹³ cannot be satisfactorily explained at the individual level—even though mediating biomedical pathways that relate to individual experiences of stress or status may be identified. Likewise, the apparent surge in excessive alcohol consumption that occurred in post-communist Russia⁶ is intrinsically a population-level process that can only partly be understood by elucidating concomitant individual-level phenomena. The individual-level perspective fails to conceptualise the population's health as a public good, as something that affects social functioning, community morale, and collective economic performance.¹⁴ Analysis at these different levels addresses complementary, qualitatively distinct, types of questions.¹¹

The public-health endeavour is thus a broad and inclusive enterprise that extends to political, social, and environmental leadership and management. It is not merely one of “the specialities in medicine”.¹⁵ Rather, clinical medicine is part of the overall public-health effort to promote and protect population health, and to reduce the impact of illness and disease. In a rapidly changing world, with new influences on population health, implementing a broad-based public health effort becomes an increasingly important challenge.

The advent and consequences of globalisation

“Globalisation” refers to various interrelated processes of global interconnectedness.¹⁶ Two core components are economic globalisation and the associated ascendancy of deregulated markets in international trade and investment. Two other important domains are technological globalisation, especially of information and communication technologies, and cultural globalisation where popular culture is increasingly dominated by the USA and the English language. There is also an emerging globalisation of ethical and judicial standards, which should render social and individual rights more secure.

The principal promoters of a globalised market-based economic system are international agencies such as the World Trade Organisation (WTO), the World Bank, the International Monetary Fund (IMF), and the transnational corporations. The main strategies have included the promotion of free trade, corporate taxation concessions, and investment incentives allied to relaxation of wage controls and workplace standards, and the contraction of national public-sector spending in the health, education, and welfare sectors.^{17,18} Structural adjustment programmes imposed by the IMF on the economies of various poor countries, promoting particularly the wealth-creating role of the private sector, have often impaired population health.^{19,20} Watts,²¹ for example, discusses how the curtailment of education under this imposed regime of economic rationalism has undone advances in literacy in women, fertility reduction, and improved reproductive health. In light of such adverse experiences the World Bank now

recognises the need for a strong State to carry out essential public functions, including public health, and to ensure well-functioning markets.²² Meanwhile, tension persists between the philosophy of neoliberalism, emphasising the self-interest of market-based economics, and the philosophy of social justice that sees collective responsibility and benefit as the prime social goal.¹⁸ The practice of public health, with its underlying community and population perspective, sits more comfortably with the latter philosophy.

The extent of economic globalisation is illustrated by the recent enormous growth in trade and foreign capital flows. Between 1973 and 1995 daily foreign-exchange turnover rose almost 100-fold, and foreign direct investment rose six-

fold.²³ These global economic changes have dramatically affected the amount and distribution of overall wealth in the world. Whereas global average per capita gross domestic product (inflation adjusted) more than doubled during the past half-century, the gains were unevenly shared, hugely widening the gap between rich and poor.²³

Alongside this economic globalisation has been the rapid development and international spread of information and com-

munication technologies, facilitated by investments in infrastructure, improved technologies, and shrinking costs. However, the reach of the telephone and internet is still limited within poor populations. In the cultural domain, globally coordinated advertising, technological innovation, and marketing opportunities are increasingly driving modern consumer behaviours, as exemplified by the intensified global promotion of tobacco products.¹⁵ Many traditional, locally-attuned, health-supporting “wisdoms” with respect to diets, physical activity patterns, local crafts, and so on have been displaced via the influences of urbanisation, automation, powerful transnational media groups, and associated lifestyle changes.²⁴

Another feature of today's world is the increase in human mobility. Most movement is voluntary; some is involuntary and in response to conflict, civil disorder, and natural disaster. The number of environmental and political refugees has increased about ten-fold since 1980,²⁵ surging particularly in the late 1990s.²⁶ Increased mobility of labour can be of mutual economic benefit—many less-developed economies welcome cheap overseas labour, and international remittances from these workers assist their home economies. Meanwhile, human mobility is also important in the enhanced transmission of ideas, values, and microbiological agents.

Globalisation and population health

From a public-health perspective, globalisation appears to be a mixed blessing.^{16,17} On the one hand accelerated economic growth and technological advances have enhanced health and life expectancy in many populations. At least in the short-to-medium term, these material advances allied to social modernisation and various health-care and public-health programmes yield gains in population health. On the other hand, aspects of globalisation jeopardise population health via the erosion of social and environmental conditions, the global division of

Rights were not granted to include this image in electronic media. Please refer to the printed journal.

Freetown, Sierra Leone: many houses in the capital still do not have running water

Examples of health risks posed by economic and other globalisation processes

The primary health risks, a result of globalisation on social and natural environments, include:

- Perpetuation and exacerbation of income differentials, both within and among countries, thereby creating and maintaining the basic poverty-associated conditions for poor health.
- The fragmentation and weakening of labour markets as internationally mobile capital acquires greater relative power. The resultant job insecurity, sub-standard wages, and lowest-common denominator approach to occupational environmental conditions and safety can jeopardise the health of workers and their families.
- The consequences of global environmental changes (includes changes in atmospheric composition, land degradation, depletion of biodiversity, spread of “invasive” species, and dispersal of persistent organic pollutants).

Other, more specific, examples of risks to health include:

- The spread of smoking-related diseases as the tobacco industry globalises its markets.
- The diseases of dietary excesses as food production and food processing become intensified and as urban consumer preferences are shaped increasingly by globally promoted images.
- The diverse public-health consequences of the proliferation of private car ownership, as car manufacturers extend their marketing.
- The continued widespread rise of urban obesity.
- Expansion of the international drug trade, exploiting the inner-urban under-class.
- Infectious diseases that now spread more easily because of increased worldwide travel.
- The apparent increasing prevalence of depression and mental-health disorders in ageing and socially fragmented urban populations.

labour, the exacerbation of the rich-poor gap between and within countries, and the accelerating spread of consumerism (panel).^{17,27-29}

Economic “globalisation” has, in fact, been a long-evolving feature of a world dominated by western society. For example, the onset of the 20th century was a time of vigorous free trade, subsequently curtailed in the aftermath of World War I. However, contemporary globalisation differs in both the scale and the comprehensiveness of change, and in the associated decline in the country’s capacity to set social policy.²⁸ Although the western world’s post-World War I international development project initially anticipated that countries everywhere would converge towards the western model of national democratic capitalism, that project has latterly evolved towards the building of an integrated and deregulated free-market global economy.³⁰ These globalising processes, in turn, have become a major determinant of national, social, and economic policies.^{18,31} Thus, although responsibility for healthcare and the public-health system remains with national governments, the fundamental social, economic, and environmental determinants of population health are becoming increasingly supranational. It has become evident that this global combination of liberal economic structures and domestic policy constraint promotes socioeconomic inequalities and political instability,¹⁸ each of which adversely affects population health. Unless the moderating role of the state or of international agencies is strengthened, increasing competition for the world’s limited natural resources is likely to damage intercountry relations, local and global environments, and population health.^{18,32}

One aspect of the growth in international trade with particularly deleterious public-health consequences has been the escalation in the sales of weapons, much of it facilitated by western governments. Sub-Saharan Africa provides many tragic examples of these effects as does the the 1999 Balkan crisis. The nature of modern conflict is such that most casualties are civilians, with women and children being particularly vulnerable.³³

Global environmental change and health

A major manifestation of the increasing scale of the human enterprise is the advent of global environmental changes. Whereas not directly caused by the globalisation processes

discussed above, global environmental change reflects the increasing magnitude of population numbers and the intensity of modern consumer-driven economies.³⁴ Humankind is now disrupting at a global level some of the biosphere’s life-support systems,^{8,35} which provide environmental stabilisation, replenishment, biological productivity, the cleansing of water and air, and the recycling of nutrient elements. Our predecessors could take these environmental “services” for granted in a less-populated world. However, today mankind is changing the gaseous composition of the lower and middle atmospheres; there is a net loss of productive soils on all continents, depletion of most ocean fisheries and many of the great aquifers upon which irrigated agriculture depends; and an unprecedented loss of overall rate whole species and many local populations.^{7,8} An estimated one-third of the world’s stocks of natural ecological resources have been lost since 1970.³⁶ These changes to the earth’s basic life-supporting processes pose long-term risks to the health of populations.^{7,37}

Global climate change

Climate scientists forecast that the continued accumulation of heat-trapping greenhouse gases in the troposphere will change global patterns of temperature, precipitation, and climatic variability in the coming decades.³⁸ A rise of 1–3°C during the next half-century, greater at high than at low latitudes, would occur faster than any rise encountered by man since the inception of agriculture around 10 000 years ago. The UN’s Intergovernmental Panel on Climate Change and various other national scientific panels have assessed the potential health consequences of climate change.³⁸⁻⁴¹ These risks to human health will arise from increased exposures to thermal extremes and from regional variable increases in weather disasters. Other substantial risks may arise because of the disruption of complex ecological systems that determine the geography of vector-borne infections (such as malaria, dengue fever, and leishmaniasis), and the range, seasonality, and incidence of various food-borne and water-borne infections, the yields of agricultural crops, the range of plant and livestock pests and pathogens, the salination of coastal lands and freshwater supplies due to rising sea-levels, and the climatically related production of photochemical air pollutants, spores, and pollens.^{40,41}

Public-health scientists now face the task of estimating, via interdisciplinary collaborations, the future health impacts of these projected scenarios of climatic-environmental conditions. Mathematical models have recently been used, for example, to estimate how climatic changes would affect the potential geographic range of vector-borne infectious diseases.^{40,42}

Stratospheric ozone depletion

Depletion of stratospheric ozone by man-made gases such as chlorofluorocarbons has been occurring during the past few decades and is likely to peak by about 2020. Ambient ground-level ultraviolet irradiation is estimated to have increased by up to 10% at mid-to-high latitudes during the past two decades.⁴³ Scenario-based modelling, integrating the processes of emissions accrual, ozone destruction, ultraviolet irradiation flux, and cancer induction, indicates that European and US populations will have a 5–10% rise in skin-cancer incidence during the middle decades of this century.⁴⁴

Biodiversity loss and invasive species

As man's demand for space, materials, and food increases, so populations and species of plants and animals are being extinguished increasingly rapidly. An important consequence for human beings is the disruption of ecosystems that provide "nature's goods and services".³⁵ Biodiversity loss also means that we are losing, before discovery, many of nature's chemicals and genes, of the kind that have already conferred enormous medical and health benefits. Myers estimates that five-sixths of tropical vegetative nature's medicinal goods have yet to be recruited for our benefit.⁴⁵

Meanwhile, "invasive" species are spreading worldwide into new non-natural environments via intensified food production, commerce, and mobility. The resultant changes in regional species composition have many consequences for human health. For example: the choking spread of water hyacinths in east Africa's Lake Victoria, introduced from Brazil as a decorative plant, is now a breeding ground for the water snail that transmits schistosomiasis and for the proliferation of diarrhoeal disease organisms.⁴⁶

Impairment of food-producing ecosystems

Increasing pressures of agricultural and livestock production are stressing the world's arable lands and pastures. We enter the 21st century with an estimated one-third of the world's previously productive land seriously damaged by erosion, compaction, salination, waterlogging, and chemicalisation that destroys organic content.^{32,47,48} Similar pressures on the world's ocean fisheries have left most of them severely depleted or stressed.⁴⁹ Almost certainly we must find an environmentally benign and socially acceptable way of using genetic engineering to increase food yields if we are to produce sufficient food for another 3 billion people (with higher expectations) during the next half century.

Modelling studies, allowing for future trends in trade and economic development, have estimated that climate change will cause a slight decrease globally of around 2–4% in cereal

grain yields (which represent two-thirds of world food energy). The estimated decrease in yield will be considerably greater in the food-insecure regions in South Asia, the Middle East, North Africa, and Central America.^{50,51}

Rights were not granted to include this image in electronic media. Please refer to the printed journal.

Bangladesh, 1998: families queue for food after a flood that affected 20 million people

Other global environmental changes

Freshwater aquifers in all continents are being depleted of their ancient "fossil water" supplies. Agricultural and industrial demand, amplified by population growth, often greatly exceeds the rate of natural recharge. Water-related political and public-health crises loom in some regions in the next few decades.³²

Various semivolatile organic chemicals (such as polychlorinated biphenyls) are now disseminated world-wide via a sequential "distillation" process in the cells of the lower atmosphere, thereby transferring chemicals from their usual origins in low-to-mid latitudes to high, indeed polar, latitudes.^{8,32} Consequently, increasingly high concentrations are accumulating in polar mammals and fish and in traditional groups of people that eat them. Various chlorinated organic

chemicals, butylytin and other compounds, adversely affect the immune systems and reproductive systems of mammals, including human beings.⁴⁸ Chemical pollution is no longer just an issue of local toxicity.

Conclusion

The mix of rapid processes of socioeconomic change, demographic change, and global environmental change in today's world requires a broad conception of the determinants of population health. A deficiency of social capital (social networks and civic institutions) adversely affects the prospects for health by predisposing to widened rich-poor gaps, inner-urban decay, increased drug trade, and weakened public-health systems. The large-scale loss of natural environmental capital—manifested as climate change, stratospheric ozone depletion, degradation of food-producing systems, depleted fresh-water supplies, biodiversity loss, and spread of invasive species—is beginning to impair the biosphere's long-term capacity to sustain healthy human life.

Scientists and policy makers face unfamiliar challenges in addressing these broader contextual issues in population health. Koopman, recognising the general challenge, states that "epidemiology is in transition from a science that identifies risk factors for disease to one that analyses the systems that generate patterns of disease".⁵² Other public-health sciences, too, will need to engage in this systems-oriented study of large-scale influences on health. We must, of course, continue to identify, quantify, and reduce the risks to health that result from specific, often local, social, behavioural, and environmental factors. Meanwhile we must anticipate the influences on population health of today's larger-scale socioeconomic processes and systemic environmental disturbances. We should take heart from the now well-advanced integration of systems-based ideas and ecological ideas across other scientific domains, including physics, the neurosciences, and evolutionary biology.^{53,54}

This human-ecology perspective will broaden the theory and practice of public health, and will help integrate the consideration of health outcomes into decision making in all policy sectors. The sustained good health of populations requires enlightened management of our social resources, economic relations, and of the natural world. There is a win-win opportunity in this situation: many of today's public-health issues have their roots in the same socioeconomic inequalities and imprudent consumption patterns that jeopardise the future sustainability of health. There are great challenges here for public-health practitioners and researchers.

References

- 1 Beaglehole R, Bonita R. Public health at the crossroads: achievements and prospects. Cambridge: Cambridge University Press, 1997.
- 2 Powles JW. Changes in disease patterns and related social trends. *Soc Sci Med* 1992; **35**: 377–87.
- 3 Acheson D. Independent inquiry into inequalities in health. London: HM Stationery Office, 1998.
- 4 Leon DA, Walt G, eds. Poverty, inequality and health. Oxford: Oxford University Press (in press).
- 5 Watson P. Explaining rising mortality among men in Eastern Europe. *Soc Sci Med* 1995; **41**: 923–34.
- 6 Leon DA, Chenet L, Shkolnikov VM, et al. Huge variation in Russian mortality rates 1984–94: artefact, alcohol, or what? *Lancet* 1997; **350**: 383–88.
- 7 McMichael AJ. Planetary overload: global environmental change and the health of the human species. Cambridge: Cambridge University Press, 1993.
- 8 Watson RT, Dixon JA, Hamburg SP, et al. Protecting our planet. securing our future: linkages among global environmental issues and human needs. UNEP/USNASA/World Bank, 1998.
- 9 Loomis D, Wing S. Is molecular epidemiology a germ theory for the end of the twentieth century? *Int J Epidemiol* 1990; **19**: 1–3.
- 10 Pearce N. Traditional epidemiology, modern epidemiology, and public health. *Am J Public Health* 1996; **86**: 678–83.
- 11 McMichael AJ. Prisoners of the proximate: epidemiology in an age of change. *Am J Epidemiol* 1999; **149**: 887–97.
- 12 Eurowinter Group. Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. *Lancet* 1997; **349**: 1341–46.
- 13 Wilkinson R. Unhealthy Societies: the afflictions of inequality. London: Routledge, 1996.
- 14 WHO. The World Health Report 1999: making a difference. Geneva: WHO, 1999.
- 15 Editorial. Putting public health back into epidemiology. *Lancet* 1997; **350**: 229.
- 16 Lee K. Globalisation and health policy: a conceptual framework and proposed research and policy agenda. *Soc Sci Med* (in press).
- 17 Kinnon CM. World trade: bringing health into the picture. *World Health Forum* 1998; **19**: 397–406.
- 18 Gray J. False Dawn: the delusions of global capitalism. London: Granta, 1998.
- 19 Hoogvelt A. Globalisation and the post-colonial world. London: Macmillan, 1997.
- 20 Bijlmakers LA, Bassett MT, Sanders DM. Socioeconomic stress, health and child nutritional status in Zimbabwe at a time of economic structural adjustment: a three year longitudinal study, Research Report Number 105. Uppsala: Nordiska Afrika Institutet, 1998.
- 21 Watts S. Epidemics in history: disease, power and imperialism. New Haven: Yale University Press, 1997.
- 22 World Bank. The state in a changing world: World Development Report 1997. Oxford: Oxford University Press, 1997.
- 23 UNDP. Human Development Report. Oxford: Oxford University Press, 1999.
- 24 Shetty P, McPherson K, eds. Diet, nutrition and chronic disease: lessons from contrasting worlds. Chichester: Wiley, 1997.
- 25 Myers N, Kent J. Environmental exodus: an emergent crisis in the global arena. New York: Climate Institute, 1995.
- 26 Red Cross. World Disasters Report, 1998. New York: Oxford University Press, 1999.
- 27 Stephens C, Leonardi G, Lewin S, Chasco MSS. The multilateral agreement on investment: public health threat for the twenty-first century? *Eur J Public Health* 1999; **9**: 3–5.
- 28 Yach D, Bettcher D. The globalization of public health, I: threats and opportunities. *Am J Public Health* 1998; **88**: 735–38.
- 29 Yach D, Bettcher D. The globalization of public health, II: the convergence of self-interest and altruism. *Am J Public Health* 1998; **88**: 738–41.
- 30 McMichael PD. Development and social change: a global perspective. Thousand Oaks CA: Pine Forge Press, 1996.
- 31 Navarro V. Comment: whose globalization? *Am J Public Health* 1998; **88**: 742–43.
- 32 UN Environment Programme. Global Environment Outlook 2000. Nairobi: UNEP, 1999.
- 33 Levy BS, Sidel VW eds. War and public health. New York: Oxford University Press, 1997.
- 34 McMichael AJ, Powles JW. Human numbers, environment, sustainability and health. *BMJ* 1999; **319**: 977–80.
- 35 Daily G, ed. Nature's Services: societal dependence on natural ecosystems. Washington, DC: Island Press, 1997.
- 36 Loh J, Randers J, MacGillivray A, et al. Living planet report, 1998. Gland: WWF International, 1998.
- 37 Last JM. Global environment, health and health services. In: Last JM, Wallace RB, eds. Public health and preventive medicine. Norwalk, Connecticut: Appleton Lange, 1992: 677–86.
- 38 Houghton JT, Meira Filho LG, Callander BA, et al. Intergovernmental Panel on Climate Change (WGII). Climate change, 1995—the science of climate change: contribution of working group I to the second assessment report of the intergovernmental panel on climate change. Cambridge: Cambridge University Press, 1996.
- 39 Climate Change Impacts Review Group (UK). The potential effects of climate change in the United Kingdom. London: DETR, 1996.
- 40 McMichael AJ, Haines A, Slooff R, Kovats RS, eds. Climate change and human health. Geneva: WHO, 1996.
- 41 McMichael AJ, Haines A. Global climate change: the potential effects on health. *BMJ* 1997; **315**: 805–09.
- 42 Martens WJM, Kovats RS, Nijhof S, et al. Climate change and future populations at risk of malaria. *Global Environmental Change* (in press).
- 43 UN Environment Programme. Environmental effects of ozone depletion: 1998 Assessment. Lausanne: Elsevier, 1998.
- 44 Slaper H, Velders GJM, Daniel JS, de Groot FR, van der Leun JC. Estimates of ozone depletion and skin cancer incidence to examine the Vienna Convention achievements. *Nature* 1996; **384**: 256–58.
- 45 Myers N. Biodiversity's genetic library. In: Daily GC, ed. Nature's services: societal dependence on natural ecosystems. Washington DC: Island Press, 1997.
- 46 Epstein PR. Weeds bring disease to the east African waterways. *Lancet* 1998; **351**: 577.
- 47 Pimentel D, Harvey C, Resosudarmo P, et al. Environmental and economic costs of soil erosion and conservation benefits. *Science* 1995; **267**: 1117–22.
- 48 World Resources Institute. World resources 1998–1999: environment and health. Oxford: Oxford University Press, 1998.
- 49 Food and Agricultural Organization. State of the world's fisheries, 1995. Rome, Italy: FAO, 1995.
- 50 Parry M, Rosenzweig C, Iglesias A, Fischer G, Livermore MTJ. Climate change and global food security: a new assessment. *Global Environmental Change*, 1999; **9**: 51–67.
- 51 UK Meteorology Office, UK Department of Environment, Transport and Regions. Climate change and its impacts. London: Met Office Communications, 1998.
- 52 Koopman JS. Emerging objectives and methods in epidemiology. *Am J Public Health* 1996; **86**: 630–32.
- 53 Capra F. The web of life. New York: Anchor, 1996.
- 54 Wilson EO. Consilience: the unity of knowledge. New York: Knopf, 1998.