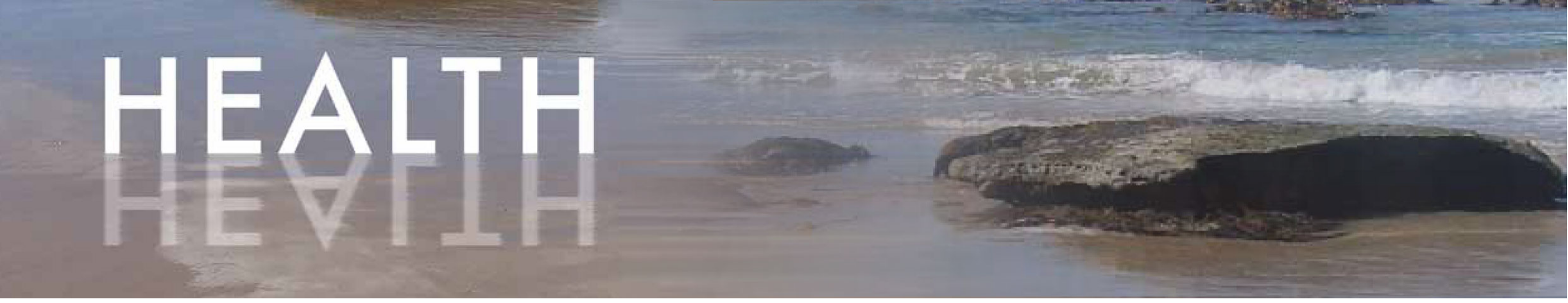

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Climate Change: Human Health Impacts — Past, Present and Future

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The year 2010 was climatically distinctive. Globally, it was one of the two hottest years in the 150-year (surface thermometer) record. It was also a tumultuous year of extreme weather events — in North America, much of Europe, and in the greater Eurasian region where the combination and scale of flooding (Pakistan and China), landslides (China), extreme heat-waves (Russia, China, Vietnam), and wild fires (Russia) during August was, literally, extraordinary. The dire and diverse impacts on human health and survival were obvious. In Moscow, during the extremes of heat and smoke pollution in July–August, around 500 more deaths occurred each day than is normal for that time of year — approximately a 50% excess. Many leading climate scientists judged that this confluence of extreme events probably points to the amplifying effect of climate change (especially warming) on weather variability.

If the year 2010 was a pointer to the sort of climatic world that we are currently heading for, how should we view the first six weeks of 2011? Devastating floods in Queensland and Victoria, Cyclone Yasi in Queensland, vast and lethal floods in Pakistan and Brazil, and crippling extremes of snowfall in northern Europe and northeast United States. As the world warms, evaporation rates increase and the warmer air holds more water vapour. Eventually when air masses collide or encounter mountain ranges, extraordinary volumes of rain or snow are released. This is all in accord with the predictions of climate scientists, first made in the 1990s. Meanwhile, our governments still refer to these recent events as no more than tragic 'natural disasters'. We seem to be slow learners.

The great weight of scientific evidence indicates that we live, today, in a remarkable and high-risk moment in human history: climate change and other human-induced global and regional environmental changes portend serious threats to life on Earth.[1,2] Yet, in the 2010 federal election campaign in Australia, the leaders of the two major political parties were too ill-informed or electorally frightened to broach serious discussion of how we should respond to the great challenge of global climate change.

The advent of these large-scale environmental changes, all of which have first emerged in recent decades, calls for serious reconsideration of how we live, the pressures we put on the natural environment, and how large a population can be sustained. Given these big questions, it is appropriate, first, to explore climate change on a larger canvas. What does it signify?

The Anthropocene: living in an extraordinary era

In just 200 years — one-tenth of 1% of the 180,000-year existence of *Homo sapiens* — we humans have done what no other species has ever done. We have begun to change the Earth system itself, to affect the planet's functioning. Various eminent scientists describe this era as the 'Anthropocene', in which humans have become the dominant force influencing and disrupting many of Earth's great natural geophysical and ecological systems.[1] The Anthropocene thus succeeds the climatically stable Holocene era spanning the past 10,000 years and, before that, the glaciation-punctuated Pleistocene era — the variable climate and environment of which shaped the evolution of the big-brained *Homo*.

This is an extraordinary turn of events: we humans are now increasingly shaping the planet's environment. This reflects the unprecedented brain-power and ingenuity of our so-called 'sapiens' (wisdom).[2] This century, to avert a crisis of non-sustainability, we must transform many aspects of the way we live: how we generate energy, produce and consume goods, build cities and transport systems, grow food, manage the natural environment, and constrain human numbers. The next two generations of Australians will almost certainly live through the Sustainability Transition, the fourth great transition in the ways that humans live. First, there was the change from hunter-gatherers to early farmers, then to city-dwellers, to industrial societies and, next, to post-industrial co-habitants and stewards of Earth's natural environment.

Without a substantial transition we will not achieve environmental and social conditions able to support human wellbeing, health and survival across future generations, globally, and equitably. In contrast, a world 100–200 years hence that might be up to 4–6°C warmer would be a world with swathes of uninhabitable areas, widely afflicted with serious shortages of food and water, and beset by frequent weather disasters. However, for the moment, this great 'sustainability' challenge remains widely misunderstood, indeed trivialised, by those who imagine it is merely about sustaining economic growth, traffic flows, infrastructure for ever-expanding suburbs, and affordable electricity. In fact, the *sine qua non* of sustainability is the need to maintain a natural world able to support all living species.

Modern urbanised populations typically live several steps removed from nature's fundamental health-and-life supports. In consequence, the usual, but erroneous, view is that 'health' is something personal, dependent on local and individual-level factors: pills, vaccinations, auspicious genes and access to health-care. In fact, and more fundamentally, population health depends most of all on food supplies, freshwater flows, stability of infectious disease patterns, natural buffering against extreme weather events (by forests, wetlands, reefs, and so on), overall social stability and the avoidance of conflict over scarce natural resources.

An awareness of the significance and nature of these population-level determinants of health is evident in the lurid biblical fantasy about the 'Four Horsemen of the Apocalypse', the four ancient scourges of population health — famine, pestilence, war and conquest.[3] Their names refer to health and survival risks to whole populations. An individual may starve, but the population experiences famine. An individual may get smallpox, but the population experiences pestilence. Those population-level scourges have flickered and flared throughout nearly all of human history. Only in the recent past have famine and pestilence receded, primarily in industrialising western countries — and hopefully long term. Meanwhile, war and occasional conquest persist as ever (and may be exacerbated in future by increasing environmental and climatic crises).

We need to acquire an understanding of the nature of these higher-order, ecological, influences on human health. Without that we cannot, in turn, understand what climate change portends for humans as communities of living organisms — not just the risks to their economies, jobs, properties, and holiday opportunities.

Climate change: part of a global environmental syndrome

Climate change is the best-known of the human-induced global environmental changes in today's Anthropocene world. The list includes:

- greenhouse gas emissions into the lower atmosphere, causing changes to the climate
- stratospheric ozone depletion (emissions of chlorofluorocarbons, other halons, nitrous oxide)
- ocean acidification (increased CO_2 uptake, threatening viability of marine productivity)

- loss of biodiversity: loss of species, local populations, and resultant ecosystem disruption
- nitrification of soils and waterways, from increase in human-generated bioactive nitrogenous compounds
- degradation of much of the world's fertile land
- depletion of freshwater (including aquifers – the 'fossil water' stores)
- exhaustion of many great fisheries.

Human actions have almost certainly already begun to change the world's climate, primarily via the build-up of greenhouse gas concentrations in the lower atmosphere.[4] This reflects the escalating size and intensity of the modern human enterprise. During the 20th century, population size increased fourfold and average per-person economic activity increased threefold. The aggregate demand by human societies for materials, energy and waste disposal now appears to be greater than this planet can sustain — indeed, recent broad-brush assessments show that for the past three decades we have been living beyond Earth's biocapacity. Globally, our ecological overdraft is now an estiamted 30% above sustainable natural limits — and the gap is widening.[5] Climate change is currently on a clearcut continuing uptrend (with its usual natural year-to-year fluctuations), and Earth's average surface temperature is now above the bound of natural historical variation over the past thousand years.

Climate change science

Today there is a generally-accepted solid core of climate change science. Suffice it to say here that nearly all the world's climate scientists agree on two fundamentals: (1) that the build-up of atmospheric greenhouse gas concentration causes heating of Earth's surface (i.e., the essential physics and chemistry of this process is understood); and, (2) that unusually rapid heating of Earth's surface is now occurring, commensurate with the observed build-up of greenhouse gases over recent decades. During the first decade of this century nearly all indices of human-induced climate change (including rates of sea-level rise, atmospheric carbon dioxide (CO_2) concentration, sea-ice melting, and frequency of very severe weather disasters) have increased.[6] Indeed, most of these changes are occurring faster than was predicted in the 1990s.

Living with natural climatic variations has always been part of human experience — and (as discussed below) has often caused great adversity and social disruption. Those natural climatic changes have mostly been smaller and slower than those we are setting in motion today. Human-induced climate change, unabated, could yet result later this century in conditions well beyond previous human experience, a world 3-4°C warmer than today.[4] (For comparison, at the extreme of the last glaciation, around 18,000 years ago, Earth's average temperature was 5-6°C lower than the average temperature during the recent post-glaciation Holocene era.)

This chapter explores what climate change portends for human health, in Australia and elsewhere, and for future generations. Better information about the current and future risks to health will broaden our understanding of the full spectrum of risks posed by climate change — lest we are tempted to continue with this great gamble with the world's future.

Health risks from climate change: what can we know and estimate?

Many of the health risks from climate change in Australia are fairly clear. After all, climate change is not an exotic new 'exposure', and it is unlikely to cause novel health problems. Rather, it will predominantly act by affecting the rate, pattern and range of occurrence of many existing health problems.[7,8] In most respects climate change is a Risk Multiplier.

In summary, the main health risks to the Australian population are as follow. Heat-waves will become more frequent and intense, causing rates of heart attacks, strokes, physical mishaps, heat exhaustion and deaths to increase —

particularly in older persons and those with underlying poor health. Injuries, deaths, bereavements and post-traumatic stress disorders will increase in communities exposed to more frequent and severe bushfires, floods, and coastal cyclones. Various mosquito-borne viral infectious diseases (dengue, Murray Valley encephalitis, Ross River virus, Barmah Forest virus, and others) are likely to undergo changes in their rates of occurrence, outbreak patterns, geographic range and seasonality. Climate change could also facilitate the entry into Australia of some 'tropical' infectious diseases not previously present. Community demoralisation and mental health disorders (especially depression) will afflict various rural regions, especially in southern Australia, as warming and drying change the environment and impair farm production.

These health impacts will be unevenly distributed within Australia — as, indeed, around the world.[9] Some places will experience greater local changes in climate than others. Lower-income groups, often with fewer community and personal resources, will generally be more vulnerable. Some remote indigenous communities, exposed to increases in climatic and environmental extremes, water shortages and impaired hygiene, will experience increases in diarrhoeal diseases, some changes in local traditional food supplies, and exposures to shifts in several types of mosquito-borne viral infections.

Within the wider Asia-Pacific region, the combination of population pressures, climate change, sea-level rise, impaired agricultural land and water shortages will heighten tensions over resources and cause displacement of people. A one-metre sea-level rise (now considered a likely outcome by 2100) would inundate half of the great Mekong Delta rice-bowl in southern Vietnam, and around one quarter of the agricultural land in Bangladesh. Low-lying island populations face multiple health risks: physical, food yields, water quality, social disruption. In Nepal, the number of districts experiencing drying and drought and the number into which malaria has spread has approximately doubled in the past three decades. Environmental refugee flows due to these various stressors are likely to increase, jeopardising the health of the displaced people, and perhaps of the host communities.[10]

The role and objectives of research

So, how can formal research assist? The primary task is to estimate the full extent of the threat posed by climate change, and to identify who will be at most risk, and the plausible range of future health risks. That information should stimulate governmental actions to abate climate change. Meanwhile, the research will also serve two other purposes. It will provide: (1) evidence useful for developing interim protection ('adaptation') measures; and (2) further stimulus for the international public health task of reducing rates of avoidable disease and death (thus leaving a lesser base of disease for climate change to 'multiply').

This, however, is not an easy arena for researchers. For epidemiologists studying environmental influences on health, not only is climate change an unfamiliar and complex 'exposure variable', but the range, scale, and timeframe of health risks extends beyond the comfort zone of mainstream research practice. Two particular challenges are that: (1) climatic conditions impinge at whole-community, even whole region, level and their health effects mostly cannot be dissected out at individual or household level; and (2) most health risks lie in the future, extending to distant decades, and occurring in response to continually changing climatic conditions.

In contrast, mainstream epidemiological research primarily makes observations in a selected local population, allowing quantitative analysis of relationships between discrete 'exposure' (or 'risk factor') variables and health outcome events. The information is usually collected at individual level, and most of the putative causal factors act directly on human biology. This more conventional epidemiological research can be done in the 'present' (i.e., now, or via prospective follow-up study) or from the recent past by using retrospective information (for example: comparing whether fluoride tablets were taken less often during pregnancy by mothers of children with dental decay than by mothers of decay-free children).

Main research thrusts

An obvious first type of research, a starting point, is to explore relationships between recent climate variations and health outcomes in order to assess the climate-sensitivity of particular health outcomes. Hence, many recent studies have examined how daily death rates vary with daily temperature. This new 'baseline' knowledge alerts researchers to which outcomes may show early evidence of change in response to climate change. It can also facilitate estimation of the proportion of the excess deaths during an extreme climate event — e.g., heat-wave or cyclone — that is attributable to an assumed underlying amplifying effect of climate change. However, there are no simple answers to such a question. Rather, one must estimate the probability distributions of each of several linked 'causal' variables, and then combine those estimates. For example, studies of suicide rates in farmers in association with climate change, droughts and impaired farm yield can involve several links along the 'causal' chain.

The second important research category is to estimate how health risks will change in future, under plausible conditions (or 'scenarios') of climate change. This usually requires assumptions about: (1) the quantitative form of the climate-health relationship under climatic conditions not previously experienced, and (2) future trends in factors that may modulate climatic impacts, such as population ageing, changes in urban environments, and access to new vaccines.

A third research category, useful for focusing policy discussion, is to estimate the proportions of the existing burdens of disease and premature deaths from climate-sensitive causes that are reasonably attributable to the (as yet limited) climate change that has already occurred. Estimations can be made for the world, for major regions and for countries. An initial, partial, estimation was made at the behest of the World

Health Organization in the early 2000s.[11] The project estimated the health impacts attributable to climate change, for four health outcomes — malnutrition, diarrhoeal disease, malaria, and flooding. The global total was approximately 150,000 extra deaths per year, for the year 2000. Virtually all of those deaths were in low-income countries, particularly in Sub-Saharan Africa and South Asia.

That number may well have doubled over the past decade as climate change has progressed and as almost an extra billion people have been added to the global population (most of them in poor and vulnerable regions). Further, if all climate-influenced adverse health outcomes were included, the number would almost certainly be much larger — at least 500,000 deaths per year. If Australia's current and recent (cumulative historical) contribution to greenhouse gas accumulation in the lower atmosphere is around 2% of the global total, then the accrued greenhouse gas emissions from Australians are currently causing around 10,000 deaths each year in poor and vulnerable populations.

Slow learners who continue to reject the reality of human-induced climate change may regard discussion of health risks as mere scaremongering. However, a glimpse in history's rear-vision mirror shows that climatic shifts can have great consequences for human health and survival. Before exploring further the health risks to Australians, let us take a glimpse.

History: are we repeating it?

In 542 AD (CE) around one-quarter of the population of Constantinople, the eastern capital of the fractured Roman Empire, was wiped out by the catastrophic Justinian Plague.[2] This explosive epidemic appears to have been the first certain major incursion into Europe of the bubonic plague, the fearsome infectious disease spread by infected fleas on infected rats. The infection appears likely to have reached Constantinople via grain ships arriving from Egypt, with their cargoes of wheat and well-fed seafaring rats. Eight centuries later, bubonic plague entered Europe again, this time via the Black Sea port-city of Jaffa. From there it spread disastrously over the ensuing two to three years as the Black Death, killing an estimated one-third of the population of western and central Europe. Various lines of research have implicated climate change as a triggering influence on these great plague pandemics.

The Justinian Plague seems likely to have been triggered by a rapid regional cooling in the mid-530s decade, spanning much of Europe, the greater Mediterranean region, Mongolia and China. The cooler temperatures, which persisted for at least half a decade, were probably due to an extreme, though still unidentified, volcanic eruption.[12] Records from that time show that bubonic plague was rife in (today's) Ethiopia and Sudan, in the upper reaches of the Nile from where the grain shipments originated. Under usual climatic conditions, the temperature on the grain-transporting river-boats travelling downstream, a journey of four to five days, was too hot for the survival of fleas and successful proliferation of plague bacteria inside the fleas and hence for transmission of the disease. In northern Africa in the cooler latter-530s, rats, fleas and bacteria could all comfortably make the journey downstream on the Nile. During the summer months of 541 AD, historical records show that a deadly epidemic broke out in Egypt's port city of Pelusium, at the Nile mouth. It quickly spread around the eastern Mediterranean coast, and may have spread by sea to Constantinople as rats stowed away for a well-fed trans-Mediterranean crossing.

The probability of the plague bacterium being seeded into Constantinople was boosted by Emperor Justinian's otherwise prudent policy of stockpiling grain, as insurance against the possibility of a siege by the menacing Germanic hordes. Thus, the Justinian Plague can be understood as a product of at least four things: (1) the presence of a major regional source of infection, (2) a change in climatic conditions, (3) intensified transport and trade, as vehicle, and (4) a large and dense, hence susceptible, urban population.

The fundamental role of climate in our lives

This historical example underscores two important points. First, climatic conditions very often set the boundaries, the limits, for the geographic and seasonal occurrence of infectious diseases. Second, other environmental, social and commercial circumstances typically determine where infectious disease spread and outbreaks actually occur. The example also illustrates the general point that changes in climatic conditions act predominantly by changing the patterns and probabilities of otherwise familiar diseases and causes of death.

The even more fundamental point to note, again, is that climatic conditions influence the very foundations of the health of populations: food production, the flows and quality of freshwater, the stability of infectious disease patterns, and so on. Nearly all of the anticipated adverse consequences of climate change — sea-level rise, reduced food yields, diminished river flows, coastal erosion, loss of biodiversity (both species and local populations), disrupted ecosystems, ocean acidification, physical hazards to property, life and limb (especially from extreme weather events), and displacement of some communities — will impair human wellbeing, health and survival. Indeed, much of the suffering of human societies over the ages, variously afflicted by hunger and famine, epidemics, conflicts and wars over diminishing natural environmental resources, has been largely due to climatic variations and shifts. The full causal explanation for such disruptions, die-offs and social disintegration is complex, and typically it is the combination of stressors that causes the critical, unmanageable, load on the system.

While acknowledging this complexity of causation, the overarching historical pattern is compelling. Many of the great societal declines were preceded or accompanied by climate change.[2,12] Around 4,000 years ago the early great civilisation of southern Mesopotamia (in modern-day southern Iraq and

Kuwait) was stressed by warming, drying, over-exploitation of irrigation water and of soils. That society's political and institutional fabric was weakened, population nutrition and health declined, armed forces contracted in size, and conquest from outside followed. In similar vein, the contractions and part-disappearance of the great Mayan civilization in eastern and southern Mexico and Guatemala followed times of increased drought and prolonged warming, around 800–900 AD. Other examples include the collapse of the Anasazi Indian society of Chaco Canyon, in the American mid-west — due to warming and serious water shortage around 1,000 years ago; and the rapid demise of the West Vikings settlement in southwest Greenland around 1,350 AD as the climate turned colder and impaired food yields.

Settling Sydney Cove

European settlement of Australia, four centuries later, provides a further, and cameo, example. In January 1788, the First Fleet arrived in Australia from London. For crew and hapless convicts, the timing was unlucky. A severe El Nino event was emerging at that time — an event that, during the next two years, would cause millions of deaths from famine in India. These events occur approximately every half-decade as a result of a huge and natural cyclical reversal in the atmospheric pressure gradient across the Pacific Ocean. The warm moist surface waters of the ocean then temporarily flow to the east, bringing rain to The Andes, but drying and drought conditions across a vast swathe to the west that streches from eastern Australia through Southeast and South Asia, to parts of Africa and even to the northeast of South America.

In that summer of 1788, conditions for the First Fleet in eastern Australia were initially cool, wet and windy. Following an initial landing at Camp Cove by Captain Phillip's advance party, they discovered a freshwater supply further inside the harbour at the soon-to-be-named Sydney Cove. The fleet re-settled there, and for the next two years the colony struggled through times of heavy rain and cold, punctuated by fierce storms. Sanitation and hygiene were difficult, and deaths from dysentery occurred. Then in mid-1790, the climate flipped and for the next two years the stifling heat, blazing sun and lack of rain caused crop failures and livestock deaths. Food rations were further reduced, and nutritional deficiencies increased. Diarrhoeal diseases persisted, sometimes fatally, exacerbated by states of exhaustion and under-nutrition.

Health risks today: more details, more examples

Now, back to the present — where climate change is beginning to cast a long shadow over the prospects for human health, survival and social stability.

Not all health impacts of climate change will be adverse. Some mosquito-borne diseases such as malaria may recede where conditions become too hot or dry for mosquitoes. Warmer winters in some temperate-zone countries may lessen the otherwise frequent mid-winter deaths due to heart attacks and strokes. Some regions, in all continents, will experience gains in agricultural yields — at least in the earlier stages of climate change. Even so, as temperatures rise further and rainfall patterns change in the longer term, and despite any initial 'fertilisation effect' from increased atmospheric carbon dioxide levels, a much greater proportion of the world population will experience declining yields, crop losses, food insecurity and nutritional deprivation.

Most public discussion of health risks from climate change in Australia has focused on the likely impact of increasingly severe heat-waves. In Victoria, the severe heat-wave of late January 2009 caused almost 400 extra deaths above seasonal expectation (about a 40% excess). The combination of higher temperatures, population ageing and denser ('urban consolidation') settlements in ever-larger cities in Australia will pose a serious challenge, including acute demands on the health-care system and emergency services. Outdoors heat-exposed workers may face particularly high risks. However, in the world's larger and poorer populations, the more serious health risks will arise from changes to infectious diseases, food yields, vulnerability to extreme weather events (floods, storms, cyclones, and so on), and physical and social dislocation.[9]

Climate and food yields

There are many signs that sustaining food sufficiency for a still-growing human population will be difficult. Even without climate change, there is a persistent base of one billion undernourished people,[13] and many other environmental stressors are pressing on regional agriculture.

The UN's Intergovernmental Panel on Climate Change (IPCC) assesses that food yields in sub-Saharan Africa may decline by around one-third by mid-century because of climate change — especially due to warming and reduced rainfall in the southern half of sub-Saharan Africa. Water shortage will impair livestock production, as will climate change impacts on the quantity, quality and cost of livestock feed. High temperatures and reduced water availability may directly impede cattle reproduction, thus lowering calving rates, milk production and general body weight with adverse consequences for dietary protein availability and hence for human (especially childhood) nutrition and health.[14]

Wheat and rice yields are also projected to decline in South Asia. The Asian Development Bank estimated, in 2010, that climate-related water stress in the Asia-Pacific region would result in a 14–20% reduction in rice production by 2050. In the greater Mekong region alone, says the Bank, adverse climate change impacts may increase the price of rice by one-third. In India there is already an increasing level of water insecurity, as underground aquifers are depleted, as populations grow, and as declines in regional rainfall emerge. As food yields fall and prices rise, the incidence of undernutrition will rise in vulnerable groups, causing adverse health effects, physical and mental, especially in young developing children.

In Australia, rainfall trends over the past three decades in the southwest and over the past decade in southeast Australia have begun to look ominously like part of a climate change 'signal'. Within the southeastern and eastern region, the Murray-Darling Basin (which accounts for three-quarters of our agricultural production) the mismanagement of river water allocations, compounded now by a decline (perhaps climate change-related) in annual flows of the headwaters in those rivers, has generated a growing crisis. Australia's Department of Climate Change has reported on the early effects of climate change in this country:

> Rainfall in south-west Western Australia has dropped by about 15 per cent. Stream flow into Perth's dams between 1976 and 2000 almost halved as a result. Research indicates that climate change has contributed to this. There is also evidence that reduced rainfall in south-eastern Australia — Victoria and the southern part of South Australia — cannot be explained by natural variations alone. Temperatures have risen across Australia and a number of consequences are already evident. We experience more hot days and fewer cold nights. Droughts are more severe because higher temperatures increase evaporation. The incidence of extreme fire weather in south-eastern Australia has increase. Warmer temperatures have led to a decline in spring snow cover in alpine regions of Australia, and there have been a number of serious bleaching events on the Great Barrier Reef over the last decade.
> — from Summary of 'Early Effects of Climate Change' (Department of Climate Change, 2010)[15]

In response to Australia's recent drought-and-drying experience, most public and policy concern has focused on food yields, farm incomes, export earnings, and community welfare. This concern has not yet extended to full recognition that these changes endanger the health of adults and children in these rural regions. Family impoverishment, anxieties, restricted food shortages, community shrinkage, exposures to more frequent weather extremes — all of these pose risks to mental and physical health, and may also influence health-related behaviours (smoking, alcohol consumption, self-medication, and so on).

Again … the importance of the population perspective

It is worth noting, again, that these risks to health play out at community or population level. As discussed previously, modern post-industrial societies, remote from the vicissitudes and rhythms of nature, foster the misleading (and neoliberal) view that our health is essentially personal. That is, we imagine it is largely determined by individual behaviour, consumer choice, genes, and luck. However, the health risks from climate change are best understood at population level, arising from climatic impacts on food supplies, freshwater supplies, natural constraints on infectious agents, frequency of extreme weather events, and general social-political stability.

Naturally, many individuals will ask: 'What are the risks to my health from climate change … and how should I protect myself?' And many health-care providers might ask: 'What should I do to lessen the risks to my patients?' These are useful questions, and they also have the secondary benefit of fostering community understanding of the nature of the risks posed by climate change. But climate change is, first and foremost, a population-level issue, in its origins and its impacts. Most of the dual task of abating climate change, while also lessening its initial impacts, therefore requires farsighted actions by Big Government — which is much more likely to occur when there is growing political pressure from an informed, voting, public.

Health co-benefits: the greenhouse cloud can have a 'bonus' silver lining

There is a further angle to the health-based rationale for arresting climate change. Ancillary health benefits can accrue to local populations when their governments undertake mitigation actions to reduce greenhouse emissions. These are in addition to the reductions in health risks that will occur globally as climate change is averted. Such 'health co-benefits' can occur as an early bonus, and save society money by reducing days off work and the direct costs of medical management. Seven such win-win opportunities are these:

1. Replacing fossil fuels as the energy source for power-stations and motor vehicles will result in cleaner air in urban and industrial environments. This will reduce the damage to lungs and to heart and blood vessels from noxious air pollutants (including sulphur dioxide, nitrogen oxides, fine particles and ozone), and diminish the risk of triggering asthma attacks. Mortality associated with ambient air pollution exposure would fall.
2. Reducing the reliance on, and hence use of, private motor vehicles in city populations would result in more people walking, cycling or catching upgraded public transport. The main health benefit would accrue from increased physical activity. This would include reductions in the prevalence of obesity and its serious (and costly) longer-term health consequences: type 2 diabetes, heart disease, arthritis and other musculo-skeletal disorders. The risks of several types of cancer may be reduced, including breast cancer in women.
3. Improved house design, construction methods and building codes will produce more energy-efficient housing. The reduction in energy consumption will be accompanied by indoor environments less exposed to extremes of temperature — heat and cold. These extremes are a major cause of serious health events and deaths during periods of sustained heat or cold extremes.
4. A related intervention in many poor rural and peri-urban households is to replace widely-used inefficient cookstoves, which burn solid fuels in small unventilated dwellings. These traditional devices, for cooking and heating, generate noxious indoor air pollution, estimated to cause 1.6 million deaths among women and their young children each year, along with much acute and chronic illness. That number of deaths is twice the annual number attributed to ambient air pollution in the world's cities. In addition to generating indoor pollutants, these age-old devices generate various greenhouse gases, including carbon dioxide and methane. Efficient cookstoves, now being introduced in rural China

and India, will reduce those greenhouse emissions while providing immediate health protection.

5. Urban design, planning and development has wide-ranging consequences for energy use and heat retention — and therefore, respectively, for greenhouse gas emissions and for patterns and levels of exposure to heat extremes. Further, green space within cities (including parks for recreation, social mixing and local food production) can enhance the microclimate, provide ventilation and cooling, while facilitating physical activity, social contact and, indeed, contact with nature — known to improve mental health. As the world population urbanises, so the environmental and health benefits from sustainable urban planning and 'metabolism' will increase.
6. Agricultural production (including land clearing) accounts for approximately one quarter of global greenhouse emissions. The livestock sector is a major contributor, particularly due to methane emissions (regurgitation) from the digestive processes of ruminant animals — cattle, sheep, buffaloes, goats and other digastric animals. Many rich populations consume much more red meat (often high in saturated fat) from these domesticated animal sources than is nutritionally optimal — and, in consequence, incur heart disease and cancer risks. Meanwhile, various low-income populations have lower levels of meat intake than is desirable for child growth and development. If, at global level, we could avert further increase in total ruminant red meat production (and consumption), while achieving a more equitable sharing between today's over-fed and under-fed populations, we would protect the climate and achieve various health benefits.
7. The inflatable elephant in the climate change policy-discourse room is population size and growth. More people means more economic activity, which means more greenhouse gas emissions. The central challenge is to increase reproductive rights and opportunities; not to suppress (via

'population control') what we might ignorantly view as undisciplined excess breeding. In poor and under-educated populations, many women have little control over their own fertility; contraception is neither available nor well understood. With contraception, maternal deaths decline (especially because there are fewer deaths at the high-risk very young and older ages), and infant and child deaths decline due to wider birth spacing.

Meanwhile … the need for adaptation

The global community of nation states, currently enmeshed in indecision and short-sighted fear of losing economic advantage relative to others, has lost valuable time over the past two decades. We no longer have the simpler option of taking early radical action to avert a dangerous level of global climate change. 'Adaptive' interventions are therefore needed to reduce the adverse impacts of the change in climate that has already occurred — and the impacts of the additional change that is 'locked in' (even if all human-generated greenhouse emissions ceased today).

Adaptation can be viewed negatively, as defeatist, or as merely a way of coping with climate change without having to change the existing economic and cultural status quo. In fact, adaptive strategies are a necessary transitional stage, to minimise in-transit damage, as the international community seeks out a way to effectively arrest climate change (i.e., 'mitigation').

Various groups and locations in Australia will be particularly vulnerable to climate change. In principle, adaptive measures should accord priority to these high-risk groups. During heat-waves, for example, deaths and hospitalisations are most likely among the elderly and frail, and those living in low-grade housing with poor ventilation and no cooling or air conditioning. Various measures would lessen the risks to these groups — early-warning systems that effectively reach the whole community; local community 'carer' schemes for vulnerable individuals; ongoing educational advice from primary health care sources; and, in the longer-term, improvements to house design (insulation, shades and blinds, tree-planting, and so on).

Other groups in Australia at above-average risk from climate change include:

- remote and indigenous communities, especially when exposed to extremes of temperature and weather patterns, and to adverse effects on local (perhaps traditional) food yields, water supplies and valued and valuable ecosystems. Vulnerability may be heightened because of limited material, professional and technical resources.
- rural communities in regions affected by warming, drying and shifts in rainfall systems — particularly in southeast and southwest Australia — who face downturns in income, job security, community cohesion and prospects for the oncoming generation.
- communities living just beyond the current geographic boundary of occurrence of climate-sensitive infectious diseases. Dengue, for example, is currently confined to northern Queensland. In future this mosquito-borne infection may extend south as temperatures rise and as rainfall, surface water and humidity (all attractive conditions for the vector *Aedes aegypti*).[16] Adaptive strategies might be best directed to those at-risk communities: local surveillance, vaccination programs (if applicable), education of local health profession to alert them to the future possible incursion of that disease.
- sectors of the population living in regions exposed to extreme weather events (which are likely to become more frequent and intense under climate change). This includes some coastal locations at risk of cyclones, storms and flooding; rural and peri-urban communities at high risks of bushfires; and regions exposed to dust storms.

Concluding comments

In recent times public concern about climate change impacts has focused most on economic consequences, due either to climate change itself or to climate change abatement strategies. This preoccupation distracts from the greater threats to the biology and ecology of the natural world, and therefore to human health and survival. As awareness grows of that more fundamental and serious threat to health, the ready recognition of the immediate health risks from heatwaves and other extreme climatic events will extend to an awareness of the ensuing risks of climate-related diarrhoeal disease, food shortages from crop damage, and mental health traumas. Subsequently, it will become clearer that the most serious and chronic health hazards for many populations will arise from declining crop yields, weakened fisheries, altered patterns of infectious diseases, and the diverse consequences of impoverishment and population displacement.

The case for adaptive strategies to lessen health risks from climate change is now widely accepted. Meanwhile, an expanded research-based understanding of the health risks due to climate change, from global to local levels, will assist Australia and other countries make the imaginative and transformative decisions that we need to survive the future in a sustainable, healthy and equitable way.

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