CHAPTER 3
Sustaining Life: Human Health–Planetary Health Linkages

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Summary Our planet is infinitely beautiful, complex, and precious. As each of us is well aware, our species has begun to alter the planet, sometimes inadvertently, sometimes negligently or even recklessly. Ecologists often ask, “How do our actions undermine nature?” We need also to invert the question, asking “How do the planetary changes to which we contribute undermine our own health and well-being?”

This query lies at the heart of the emerging field of Planetary Health. The premise of Planetary Health is this: the earth system changes we have wrought are now so far-reaching that they drive a substantial, and increasing, proportion of the global burden of disease. Because we depend on stable earth systems to survive and thrive, environmental destruction amounts to self-destruction. We need to understand these consequences. Based on that understanding, we need to reexamine many of our core assumptions about our place on the earth. Finally, we need to deploy both scientific insight and conceptual reorientation to inspire, and to guide, corrective action.

This chapter begins with several examples of the ways in which planetary changes threaten human health and well-being—the human dimensions of planetary boundaries, as described by Will Steffen and colleagues at the Stockholm Resilience Centre (Steffen, Richardson, Rockstrom et al., 2015). The first is climate change. While the consequences of climate change range broadly, from air pollution to mental health to infectious disease, this chapter focuses on just one aspect: the effects of heat—an apparently straightforward hazard that when explored reveals great complexity. But even if there were no climate change, we would still need the field of Planetary Health, because other global-scale changes are also affecting health and well-being. Three examples discussed here are chemical contamination, land use changes, and biodiversity loss. For each of these four examples, I submit,

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the science paints a clear and sobering, if not yet complete, picture: global environmental change threatens human health and well-being.

Reviewing the relevant science behind these four examples raises far-reaching questions. What are the implications of Planetary Health for the conceptual paradigms we use to apprehend the natural world and our place in it? To what extent does conventional biomedical ethics provide a sufficient ethical framework for considering these phenomena? The chapter ends with a consideration of these questions.

Science

Of the planetary changes that affect human health, *climate change* is perhaps the best recognized. Climate change threatens human health through many pathways, as graphically depicted by the Lancet Commission on Health and Climate Change (Watts, Adger, Agnolucci et al., 2015). Some are primary and direct, such as those due to heat and severe weather events. Others are secondary, such as infectious disease risks that are mediated by earth system changes. Still others are tertiary, such as armed conflict and population displacement, mediated by more diffuse and complex social disruptions (McMichael, 2013). Of course, these categories overlap considerably. Every important category of human health outcome is affected: infectious diseases, noncommunicable diseases, traumatic injuries, mental distress and illness. Consider the effects of heat. Excessive heat causes a well-known cascade of medical consequences, from the relatively mild and self-limited heat rash and heat cramps, to more severe heat exhaustion and potentially fatal heat stroke. People die during heat waves, sometimes in frightful numbers. Those who are most vulnerable are the very young and very old, the poor and socially marginalized, those who live alone, and people with certain medical conditions (Kovats & Hajat, 2008). Most of the deaths that occur with extreme heat are not recognized or certified as heat-related; they occur from underlying illnesses such as cardiovascular disease. Heat waves can have substantial population impacts—70,000 deaths during the 2003 European heat wave (Robine, Cheung, Le Roy et al., 2008), 54,000 in Russia during the 2010 heat wave (Revich, 2011), and thousands per year in India—not well quantified—during the summers of 2010, 2013, 2015, and 2016 (Mazdiyasni, AghaKouchak, Davis et al., 2017). People can adapt to heat, but only up to a point (Hanna & Tait, 2015)—and with more frequent, more intense, and longer-lasting heat events coming, that point will be increasingly exceeded (Im, Pal, & Eltahir, 2017; Jones et al., 2015; Lelieveld et al., 2016; Mueller, Zhang, & Zwiers, 2016; Pal & Eltahir, 2015).

But heat threatens health and well-being in less obvious ways. Heat may predispose people to violence and crime; crime rates rise on hotter days (Anderson, 2001; Gamble & Hess, 2012; Schinasi & Hamra, 2017). Heat may predispose people to self-harm as well; some data suggest an association between heat and suicide (Dixon & Kalkstein, 2016; Dixon, Sinyor, Schaffer et al., 2014; Kim, Kim, Honda et al., 2016; Williams, Hill, & Spicer, 2015). Heat seems to increase the risk of kidney disease (Glaser, Lemery, Rajagopalan et al., 2016)—a problem that especially targets workers in low-income countries who toil in high temperatures without adequate rehydration (Tawatsupa, Lim, Kjellstrom, Seubsman, & Sleigh, 2012; Wesseling, Aragon, Gonzalez et al., 2016). In hot conditions, it is more difficult to protect food and water from bacterial contamination; the incidence of diarrheal diseases such as Shigella and Campylobacter rises during hot weather (Kovats et al., 2004; Levy, Woster, Goldstein, & Carlton, 2016). Heat compromises the quality of sleep (Obradovich, Migliorini, Mednick, & Fowler, 2017); sleep deprivation, in turn, is a risk factor for inflammatory conditions, metabolic and neuroendocrine abnormalities, and cardiovascular disease (Cappuccio, Cooper, D'Elia, Strazzullo, & Miller, 2011; Irwin, Olmstead, & Carroll, 2016; Knutson, Spiegel, Penev, & Van Cauter, 2007). People reduce their physical activity during hot weather (Obradovich & Fowler, 2017); being more sedentary increases the risk for cardiovascular disease (Biswas, Oh, Faulkner et al., 2015; Lee et al., 2012). Similarly, heat reduces work capacity (Dunne, Stouffer, & John, 2013; Kjellstrom et al., 2016), to the point that economic output may decline substantially in very hot places—compounding poverty in such places. Workers are affected in another way: workplace injuries rise during hot weather (McInnes et al., 2017; Otte Im Kampe, Kovats, & Hajat, 2016). In these and other ways, both direct and indirect, through mechanisms that range from sleep loss to food poisoning to deepening of poverty, heat threatens health and well-being—and heat is just one of the pathways through which climate change undermines public health.

A second planetary change is the *widespread dissemination of synthetic chemicals* through the world's ecosystems. Plastics, a family of polymers of ethylene, propylene, styrene, vinyl chloride, and other simple molecules, are emblematic. Large-scale production of plastics began in the years after World War II. Global production of plastics has now reached 300 million metric tons per year, or about 40 kg for each man, woman, and child on earth, and accounts for about four percent of the global petroleum supply (Thompson, Moore, vom Saal, & Swan, 2009). That may not sound like much. But given the current average life expectancy of 71 years, this means that, on average, each of us will account for over 2800 kg of plastic production during the course of our lives, or 30 or 40 times our body weight.

Plastics are persistent. If Michelangelo had sipped water from plastic bottles while painting the ceiling of the Sistine Chapel 500 years ago, those plastic bottles would still exist. As one commentator put it, with just a bit of hyperbole, "every piece of plastic ever made still exists today" (Every piece of plastic ever made still exists today, 2015). That is not completely true; after four or five centuries, some plastics do degrade, and of the roughly 8.3 billion metric tons of plastic that have been produced to date, a bit over a tenth has been incinerated (Geyer, Jambeck, & Law, 2017). But that still means that for every human being now alive, there is, somewhere in the world, about one metric ton of plastic. Some of it is still in use, but well over half of it is waste. Some of this is in large pieces, some is pellet-sized, and some has broken down to microplastics.

Where is it? Some of the waste is in landfills. Some ends up in waterways—a common and heartbreaking sight in many of the world's major cities, especially in low- and middle-income countries. Plastic generally floats, so it travels with currents and accumulates in eddies, forming patches that can be as large and imposing as islands. From streams, rivers, and harbors, the waste winds its way to oceans, where it continues to move under the influence of wind and currents. According to one recent estimate, between 4.8 and 12.7 million metric tons of plastic waste entered the oceans in 2010 (Jambeck, Geyer, Wilcox et al., 2015).

The plastic seems to go everywhere, making this a global problem (Barnes, Galgani, Thompson, & Barlaz, 2009). It has been found in the deepest ocean trenches, in arctic ice, on the shores of remote islands. According to the United Nations Environment Programme, "Microplastics have been detected in environments as remote as a Mongolian mountain lake and deep sea sediments deposited five kilometres below sea level" (UNEP, 2016, p. 32). The world's ocean systems tend to concentrate waste in the great ocean gyres of the North and South Pacific, the North and South Atlantic, and the Indian Ocean. The highest concentration of plastic debris ever measured on a beach was on remote Henderson Island, in the South Pacific, 5000 km from the nearest significant human habitation—but on the western edge of the South Pacific gyre (Lavers & Bond, 2017).

The plastics permeate ecosystems. We now know that some birds confuse plastic bits with food, and ingest the plastic—but cannot digest it. An estimated 90% of seabirds now have plastic in their bodies (Wilcox, Van Sebille, & Hardesty, 2015). The albatross is one such bird. Traditionally a sign of good luck for sailors, later a symbol of guilt in Samuel Taylor Coleridge's *Rime of the Ancient Mariner,* it takes on new metaphorical power in the Anthropocene, as a graphic warning of our environmental recklessness—the seabird over the ocean as the Planetary Health equivalent of the canary in the coal mine (Millow, Mackintosh, Lewison, Dodder, & Hoh, 2015).

Nor are birds the only affected species. In one recent study, investigators purchased fish and shellfish from markets in Indonesia and California, and assessed them for plastic debris. They found it in 28% of the individual fish and 55% of species sampled in Indonesia, and in 25% of individual fish and 67% of species sampled in the USA (Rochman, Tahir, Williams et al., 2015). When we eat fish, we are eating plastic.

When ecosystems are infused with plastics, human health can suffer (Efferth & Paul, 2017). Importantly, about 7% of plastic, on average, consists not of the polymers themselves, but of additives such as plasticizers, fillers, and flame retardants (Geyer et al., 2017). Moreover, plastics and microplastics, especially polypropylenes, polyethylenes, and polystyrenes, are efficient carriers of synthetic organic chemicals such as polychlorinated biphenyls (PCBs) and other PAHs, which adsorb to their surfaces (Lee, Shim, & Kwon, 2014; Rochman, Hoh, Hentschel, & Kaye, 2013; Rochman, Manzano, Hentschel, Simonich, & Hoh, 2013; Teuten, Saquing, Knappe et al., 2009). Many of these chemicals are highly persistent in the environment, hence the term Persistent Organic Pollutants, or POPs. Indeed, environmental loading with such chemicals is a defining feature of the Anthropocene (Diamond, 2017; Diamond, de Wit, Molander et al., 2015).

POPs are fat-soluble. They bioconcentrate within the fat of organisms such as fish, cattle, and polar bears, and they are biomagnified as they move from lower to higher trophic levels of food webs (Corsolini & Sara, 2017; Mackay & Fraser, 2000). POPs have become widely distributed across the globe, even in ecosystems such as the Arctic, far from where they were ever produced or used (Hung, Katsoyiannis, Brorstrom-Lunden et al., 2016; Rigét, Bignert, Braune, Stow, & Wilson, 2010).

When POPs are widely distributed through ecosystems, human exposure is unavoidable. Measurement of population tissue levels of POPs has revealed nearly ubiquitous body burdens in human populations (Fisher, Arbuckle, Liang et al., 2016; Fourth National Report on Human Exposure to Environmental Chemicals. Updated Tables, 2017; Koch & Calafat, 2009; Porta, Puigdomenech, Ballester et al., 2008; Pumarega, Gasull, Lee, López, & Porta, 2016). Many of these chemicals are biologically active, affecting neurodevelopmental, endocrine, metabolic, and other delicately balanced systems in humans and in animals. Consider the many chemicals collectively known as endocrine disrupters, which either block or activate receptors in sex hormone, thyroid, and other pathways. Synthetic organic chemicals that act in this manner include PCBs, bisphenols (e.g., bisphenol A, or BPA), organochlorine pesticides, brominated flame retardants, and perfluorinated substances (perfluorooctanoic acid, or PFOA, and perfluorooctane sulfonate, or PFOS).

Evidence suggests that these exposures play a role in several noncommunicable diseases, through both epigenetic and non-epigenetic mechanisms (Barouki, Gluckman, Grandjean, Hanson, & Heindel, 2012; Hou, Zhang, Wang, & Baccarelli, 2012; Meeker, Sathyanarayana, & Swan, 2009; Vandenberg, Colborn, Hayes et al., 2012). POPs exposure has been associated with metabolic conditions such as adiposity, insulin resistance, and dyslipidemias (Cano-Sancho, Salmon, & La Merrill, 2017; Grandjean, Henriksen, Choi et al., 2011; Lee et al., 2011; Lee et al., 2011; Lee, Lee, Song et al., 2006). One recent study of First Nation Inuit natives in the Canadian Arctic found that those with the highest levels of blood PCBs were 1.9–3.5 times more likely to have diabetes than those with the lowest levels (Singh & Chan, 2017). The concept of chemical obesogens is well established (Cano-Sancho et al., 2017; Darbre, 2017; Wassenaar & Legler, 2017). POPs exposure has also been associated with increased risk of some cancers, especially non-Hodgkin's lymphoma (Freeman & Kohles, 2012) and hormone-responsive cancers such as those of the breast, ovaries, and prostate; to date, the animal evidence is more extensive than the human epidemiologic evidence (Gore, Chappell, Fenton et al., 2015; Soto & Sonnenschein, 2010). POPs may increase the risk of thyroid disease, neurobehavioral disorders, and reproductive dysfunction (Gore et al., 2015).

There are many features of global chemical contamination we do not fully understand: its geographic extent, its pathways through ecosystems, its full impacts on human health, to what extent these exposures account for rising trends in some diseases, where are the boundaries we should not cross. But as the Lancet Commission on Pollution and Health recently made clear (Landrigan, Fuller, Acosta et al., 2017), this planetary change does no favors to ourselves or to ecosystems.

A third example of global environmental change that affects human health is *land use change*. The pressures of a growing human population and its resource demands have led to dramatic expropriation of land and water globally (Foley, DeFries, Asner et al., 2005; Lambin, Turner, Geist et al., 2001; Turner, Lambin, & Reenberg, 2007). As much as half the world's ice-free land surface has been transformed, much of it converted from natural grassland or forest to cropland and pasture for grazing (Turner et al., 2007). These changes have far-reaching effects, on such domains as biodiversity (Newbold, Hudson, Arnell et al., 2016; Newbold, Hudson, Hill et al., 2015). They also have far-reaching effects on human health. Consider two examples.

The effects of land use change and the resulting ecosystem alterations on infectious disease risk have long been appreciated and described for diseases as diverse as malaria, schistosomiasis, hantavirus pulmonary syndrome, Lyme disease, and West Nile virus (Bauch, Birkenbach, Pattanayak, & Sills, 2015; Pongsiri, Roman, Ezenwa et al., 2009). Many mechanisms contribute, from changes in microbial ecology to increased contact between humans and vectors.

A recently published example is instructive. A team of investigators based at the University of Vermont was interested in the effect of degraded watersheds on children's health. They studied nearly 300,000 children under 5 years of age in 35 countries (Herrera, Ellis, Fisher et al., 2017). Their primary exposure measures were of watershed quality—the hydrologic influence of upstream livestock, people, and tree cover on downstream water quality. Their primary outcome of interest was diarrhea—an important condition, as it is the second leading cause of death among children in the under-5 age group (Pruss-Ustun, Bartram, Clasen et al., 2014), responsible for about 448,000 deaths in 2016 (Global Burden of Disease, 2017). The Demographic and Health Surveys program provided health and socioeconomic data, and geolocated climate and watershed data came from the WaterWorld model. After controlling for socioeconomic factors, the presence of improved water and sanitation, and other potential confounders, the investigators found that more intact tree cover in the upstream watershed reduced rural children's probability of diarrhea. Thirty percent more tree cover offered roughly the same protection as improved sanitation infrastructure (but not as much as wealth, education, or an improved water supply). Healthy tree cover in a watershed is good for human health.

A second example of the impact of land use change on health comes from palm oil production in South Asia. Production is increasing as a result of demand for biofuels in Europe and food in India, Indonesia, and China. Oil palm plantations affect local ecology; they are consistently less biodiverse than primary forests, with only about 50% of the vertebrate species found in primary forests (Savilaakso, Garcia, Garcia-Ulloa et al., 2014). To clear tropical forests in Indonesia for palm oil production (as well as for other purposes, such as timber plantations), fire is commonly used; the resulting smoke blows in defined ways, affecting populations in Indonesia and the Malay Peninsula. This smoke, containing fine particulate matter, is an established risk factor for cardiovascular mortality; in fact, the smoke from such fires accounts for over 250,000 global deaths annually (Johnston, Henderson, Chen et al., 2012; Marlier, DeFries, Kim et al., 2015). A team of investigators based at Harvard has studied this phenomenon over recent years, innovatively combining data on land types, land use, fire occurrence, wind patterns, smoke composition, and health outcomes (Kim, Jacob, Mickley et al., 2015; Koplitz, Mickley, Marlier et al., 2016; Marlier et al., 2015; Marlier, DeFries, Voulgarakis et al., 2013; Spracklen, Reddington, & Gaveau, 2015). The Indonesian fires were found to cause, on average, approximately 11,000 excess regional deaths each year, but in a pattern that varies considerably with such factors as El Niño (Marlier et al., 2013). In an especially bad year, 2015, the toll was an order of magnitude higher, at just over 100,000 excess deaths (Koplitz et al., 2016). In addition, the smoke is not the only health impact of palm oil production. The loss of forests and the combustion of peat contribute to climate change. Furthermore, dietary palm oil contains highly saturated fatty acids, which have been proposed as a risk factor for heart disease and other noncommunicable diseases (Basu et al., 2013; Ismail, Maarof, Ali et al., 2018).

The final example of global environmental change I will mention is *biodiversity loss*. Biodiversity loss has accelerated dramatically during the Anthropocene (Cardinale, Duffy, Gonzalez et al., 2012; Newbold et al., 2016). While this has numerous potential impacts on human health (Bernstein, 2014), two examples are especially illustrative: pollinator loss and fisheries depletion.

Pollination by insects is an important form of reproduction for more than 35% of the annual global food production by volume. At least 87 major food crops, and up to 40% of the world's supply of some micronutrients, such as vitamin A, depend on pollination by insects (Klein, Vaissière, Cane et al., 2007). Pollinators are declining in many parts of the world for a combination of reasons, including habitat loss, pesticide use, and parasitic infestation. Pollinator loss can reduce the amount of fruits, vegetables, nuts, and seeds in the diet, contributing to vitamin A and folate deficiencies. A recent analysis projected that a 50% loss of pollination would cause about 700,000 additional deaths worldwide, mostly as a result of increased ischemic heart disease and stroke due to reduced fruit and vegetable consumption (Smith, Singh, Mozaffarian, & Myers, 2015).

Fisheries depletion has emerged as a global problem, with about 90% of fisheries now at or beyond maximum sustainable levels of exploitation (FAO, 2016). Climate change will intensify this problem in the coming decades (Comte & Olden, 2017). For many populations, fish are a leading dietary source of protein, micronutrients (often in highly bioavailable form), and omega-3 fatty acids (mainly from oily fish). Dietary omega-3 fatty acids may reduce ischaemic heart disease risk, although evidence remains inconsistent (Balk & Lichtenstein, 2017; Rangel-Huerta & Gil, 2017). In addition, through gene regulation, anti-inflammatory effects, or other mechanisms, omega-3 fatty acids may play a role in preventing and/or treating other conditions such as cancer (Lee, Sim, Lee, & Na, 2017) and arthritis (Senftleber, Nielsen, Andersen et al., 2017). However, reductions in fish stocks could limit these potential benefits. For example, the UK is unable to meet healthy diet guidelines for its population from its domestic catch, and fish intake fell to only 19% of the recommended level in 2012 (Thurstan & Roberts, 2014). One study projected that more than 10% of the global population could face micronutrient and fatty-acid deficiencies due to fish declines over coming decades, especially in low-and middle-income nations near the equator (Golden, Allison, Cheung et al., 2016). Fortunately, there is some indication that with aggressive management, collapsed fisheries can recover, as may be happening with the North Atlantic cod fishery, which abruptly collapsed in 1992. Aquaculture is to some extent replacing wild fish catches, but most aquaculture (70% in 2012) depends on external feedstocks that may be unsustainable (FAO, 2016). Challenges such as disease in farmed fish (Stentiford, Neil, Peeler et al., 2012; Stentiford, Sritunyalucksana, Flegel et al., 2017), chemical contamination of farmed fish (Hamilton et al., 2005; Jacobs, Covaci, & Schepens, 2002), genetic contamination of wild fish stocks (Cognetti, Maltagliati, & Saroglia, 2006), and pollution of waters near fish farms (Cao, Wang, Yang et al., 2007) must be addressed if sustainable aquaculture is to be achieved.

These four sets of examples—climate change, chemical contamination, land use changes, and biodiversity loss—together paint a compelling picture. Human disruptions of planetary systems threaten human health and well-being. Those who are most at risk from these disruptions are those who live each day with high levels of risk, due to poverty and deprivation.

Ways of Thinking and Knowing

This has been a grim litany. Indeed, planetary changes are threatening human health and well-being—even civilization as we know it—on a frightening scale. But the news is not all bad. Some planetary changes may offer benefits, such as higher agricultural yields, or more physical activity, in cold areas that are becoming warmer. More importantly, the steps we need to take to address planetary challenges such as climate change yield a range of co-benefits, such as stronger communities, cleaner air and more wholesome food. In the meantime, the threats I have described call on us to change our thinking, as scientists and as global citizens, in some fundamental ways—addressing what the Rockefeller Foundation–Lancet Commission on Planetary Health called *imagination challenges* (conceptual and empathy failures) and *research and information challenges* (knowledge failures) (Whitmee, Haines, Beyrer et al., 2015).

First, we need to learn to *acknowledge, and live within, limits* (Butler, 2017). We have all lived our lives during the last half of the twentieth century and the first part of the twenty-first century—a time of plenty unprecedented in human history. What enabled this, of course, was our profligate consumption of energy and materials, propelled by ever more powerful technologies. The years during and after World War II were a time of widespread limits, even in wealthy countries, and of course, those who are poor face limits every day. But for the most part, we are no more conscious of our extravagance than fish are conscious of water. And as we have learned from recent behavioral economics research, we humans are wired *not* to confront limits (Lorenzoni, Nicholson-Cole, & Whitmarsh, 2007; Shu & Bazerman, 2011; Weber, 2017). We are biased toward short-term thinking and we discount future consequences. We have a status-quo bias; we cling to what we have and are averse to making what we see as risky change. We are lousy at probabilistic thinking. We need to work to replace profligacy with restraint, extravagance with modesty, wastefulness with thrift.

Second, we need *systems thinking*. Every serious thinker about sustainability, or climate change, or human affairs in general, knows that reductionist, linear thinking misses the mark. Nowhere is this truer than in Planetary Health. But still, university departments, government agencies, and foundations organize themselves in silos, without enough cross-links. Too many donors remain infatuated with silver bullet technical solutions, rather than aiming for patient, long-term adaptive management of complex systems. In my own field, medicine, why do we still require prospective students to have studied chemistry, physics and calculus, but not ecology and evolutionary biology? We need thinking habits and institutional arrangements to be based on systems.

Third, we need a sense of *urgency*. Our house is on fire, and we need to act accordingly. Our scientific discourse is typically sober and dispassionate, but passion in this setting is no sin; rather, it is a necessity. Fifty years ago, discussing a very different emergency, the Vietnam War, Martin Luther King wrote words that are deeply appropriate today: “We are now faced with the fact, my friends, that tomorrow is today. We are confronted with the fierce urgency of now. In this unfolding conundrum of life and history, there is such a thing as being too late. Procrastination is still the thief of time. Life often leaves us standing bare, naked, and dejected with a lost opportunity. The tide in the affairs of men does not remain at flood—it ebbs. We may cry out desperately for time to pause in her passage, but time is adamant to every plea and rushes on. Over the bleached bones and jumbled residues of numerous civilizations are written the pathetic words, ‘Too late’. There is an invisible book of life that faithfully records our vigilance or our neglect. Omar Khayyam is right: ‘The moving finger writes, and having writ moves on’” (Beyond Vietnam, 1967). As it was then for Reverend King, so it is now for us. We must confront the “fierce urgency of now.”

Fourth, we need *intellectual humility.* Modern science and technology, animated by positivism for the last few centuries, have delivered untold benefits to humankind. But they have also brought wicked problems and profound dilemmas. Science and technology do not offer all the answers. We scientists need to be open to other intellectual traditions, to faith traditions (Bingham, 2016; Francis, 2015; Hayhoe & Farley, 2009) (and I am so appreciative of Pope Francis and of the Pontifical Academy of Sciences for engaging the challenges of climate change and health, and for convening us) and to the traditional ecological knowledge of indigenous peoples (Finn, Herne, & Castille, 2017; Gomez-Baggethun, Corbera, & Reyes-Garcia, 2013). This will take us beyond our comfort zones—the right place to be when we need to be stretching toward solutions.

Ethics

Let me close with a word about ethics. As a medical student and young physician, I learned and took seriously the principles of biomedical ethics: respect for autonomy, non-maleficence, beneficence, and justice. These principles guided some very sound decisions: Do not treat a patient without his or her consent. Do not withhold information from a patient. These are all well and good, but they are not nearly enough. Biomedical ethics has been far too confined to clinics and hospitals (Macpherson, 2013).

We need an ethics that recognizes everybody's right to have access to the clinic in the first place—and not only to the clinic, but to all of the precursors needed for a fully expressed and healthy life: education, housing, political voice. This is an ethics of social justice. It is essential in Planetary Health for both practical and moral reasons; those who are most vulnerable to all the threats I discussed are the disenfranchised, those without voice, those who must be at the center of any system of ethical principles (Shue, 2014). We need an ethics that recognizes intergenerational responsibility. Our obligations extend well beyond our own lifetimes (Weston, 2008).

Finally, we need an ethic that extends from humans to the more-than-human world (Leopold, 1949; Rolston, 1989). As much as we bear responsibility for each other, we bear responsibility for other species, and for ecosystems. At the very least, this responsibility is derivative from conventional ethics; Planetary Health science makes clear that care for people intrinsically includes care for the earth. But it may go further, suggesting an ethical system grounded in our place as part of the larger world we share.

Conclusion

We are living in a Golden Age. Prosperity has increased around the globe, poverty has been reduced, and human health has never been better. But, in the words of the Rockefeller Foundation–Lancet Commission on Planetary Health, "we have been mortgaging the health of future generations to realize economic and development gains in the present" (Whitmee et al., 2015). As scientists, we have increasingly uncovered and quantified the human health impacts of disrupting earth systems and crossing planetary boundaries. We need to continue this task, with ever-greater sophistication and accuracy, creating and using scientific frameworks appropriate to the complexity of the challenges, and with intellectual humility. Just as important, we need to act on the science, with passion for sustaining life, with urgency, with a drive for social and environmental justice, ever mindful of the great privilege we have: to choose the legacy we leave.

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