

Commentary Commentaire

Veterinary medicine for a world in crisis*

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I am deeply honored to participate in this annual event in celebration of both Francis Schofield (1) and progress of the veterinary sciences. Francis Schofield seems to have been a maverick among veterinarians of his time on 2 fronts; 1) because he placed great value on scientific inquiry at a time when his profession considered this rather peripheral to its needs, and 2) because he insisted that each person, perhaps especially each veterinarian, had an ethical obligation to address the major social issues of the world. He himself spent his 1st and last professional years working for social justice in Korea (2). I hope today's lecture is in keeping with the tradition of the series, and with Francis Schofield's influence.

I believe our world, our human society, is at a moment of crisis. "Crisis" does not mean "disaster;" rather, it means a critical turning point, when the right decisions can affect the future in truly spectacular ways, but also, when wrong decisions can be fatal, or, at best, will return us to the stone age. The crisis we face is largely ecological and derives from the question, "How many people can the earth support in the long run, and with what quality of life?" We have delayed asking and answering this question until our combined numbers, needs, and wants have exceeded our income and exhausted our savings and credits. We are left with nothing but our wits. Veterinarians, with their special education in animal health, have an important role to play in managing this global crisis through to a favorable outcome for humankind. I join with Francis Schofield in believing that the veterinary profession also has a social obligation to engage fully with the critical issues that will determine our collective future.

A view from the wild side

I have spent most of my veterinary career dealing with issues of health and disease in wild animal populations. I have come to realize that this "view from the wild side," this wildlife lens through which I have viewed health and disease, is very different from the lens of strictly clinical medicine, which so dominates current medical vision. It is a wide-angle, landscape lens that offers both clinical and ecological perspectives. These combined

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perspectives are as relevant to the health and well-being of people and domestic animals as they are to wildlife. It is this perspective, and its implications, that I want to share with you today.

Historical background

The perspective is not new. It has historic roots back to the 19th century. Two seminal thinkers from the past who have provided the foundations of this perspective on health and disease are Rudolf Virchow and Aldo Leopold.

Rudolf Virchow, a German physician active from the 1840s to the 1890s, was a true father of modern medicine because he established the scientific study of disease pathogenesis (3). Every medical practitioner and scientist active today owes a thick slice of his or her daily bread to Rudolf Virchow. Virchow insisted on scientific evidence and doubted easy or mystical explanations. For example, he embraced the discovery of bacterial pathogens by his contemporaries, Louis Pasteur and Robert Koch, but he also doubted that the causes of all diseases could be reduced to a list of infectious pathogens. He had a broader view of cause. As a young military physician in the 1840s, Virchow was sent to a remote area of what is now southwestern Poland to investigate an epidemic that was devastating the region. He returned and reported that the people there were dying of typhus. But with remarkable insight, he also reported that the cause of the epidemic was poverty and that further epidemics could be prevented by the provision of freedom, improved roads, and good schools (4). So Virchow taught us to formulate our ideas and decisions on the basis of good evidence, and to take a very wide-angle view of what causes disease.

Aldo Leopold, an American ecologist active during the first half of the 20th century (5), witnessed the monumental environmental changes caused by European settlement of the American west, culminating in the disastrous dust bowl, and he pioneered a new science of applied ecology, aimed at reversing the worst of the damage. As a practitioner of this new science, he showed that it is possible to intervene in nature to improve the function and stability of damaged ecosystems. But to do so successfully, it is necessary, as he put it, "to think like a mountain," by which he meant, to understand fully the complexity of cause and effect in ecological processes, and to plan and act on time scales of decades and centuries (5,6). So, Leopold taught us that remediation, even at the level of large and complex ecosystems, is difficult but possible, if we can think like a mountain.

The great majority of my personal experience with health and disease has been in association with the evolution of the Canadian Cooperative Wildlife Health Centre (CCWHC). The CCWHC is a distributed academic wildlife health sciences

centre with a unit at each of Canada's veterinary colleges. It is, most fundamentally, a partnership for wildlife health science among the veterinary colleges, and between these colleges and the government agencies with public responsibilities for wildlife, agriculture, and public health. The Centre was developed conceptually between 1986 and 1992; it became operational in August 1992 and has been evolving ever since. The impetus for the Centre was the apparently growing importance of disease in wildlife conservation and management programs across North America in the early 1980s. Only in the mid-1990s did we realize that these seemingly new disease problems in wildlife were just one part of the world-wide phenomenon of emerging infectious diseases: of new diseases seemingly arising out of nowhere at an alarming rate and of old familiar diseases suddenly manifesting in new, problematic forms. So the Centre was established on the global rising curve of emerging infectious diseases. As a consequence, it has also been caught up in the escalating needs of Canadian society to deal with the onslaught of new and unanticipated disease issues, first in wildlife management and conservation, but then quickly also in livestock and public health.

It is fair to say that, in 1992, the only wildlife disease issues of recognizable public concern were rabies in any species and, perhaps, brucellosis and tuberculosis in the bison of Wood Buffalo National Park. In contrast, today, a great many Canadians would recognize and register concern about *West Nile virus* infection; avian influenza; chronic wasting disease; severe acute respiratory syndrome (SARS); tuberculosis, now also in elk and deer in Manitoba; the raccoon strain of rabies menacing Ontario, Quebec, and New Brunswick; monkey pox in the pet trade; Lyme disease in the back yard; and *Hanta virus* pulmonary syndrome from dust in the cottage.

These same 2 decades of the Centre's evolution also witnessed another important development. A new scientific discipline, disease ecology, arose as a fresh and defining science for understanding the kaleidoscope of disease patterns abroad in the world (7–10). It offered new insights and approaches to understanding particularly the environmental and ecological contexts of disease occurrence. As a new discipline, it displayed a fertile hybrid vigor from a new fusion of ecology with medicine.

The Centre's first decades have been exciting and eye-opening. Let me offer you 4 conclusions that I have drawn from this experience and that, I think, also form a useful framework for considering how veterinary medicine can orient itself to address the most pressing health and disease issues of our time.

1. Disease is good

On a personal level, that disease can be good is an absurd assertion. Disease is not good when I am sick or you are sick, or my child or my dog is sick, or when any fellow creature, man or beast, suffers from illness. Yet, in a broader context, pathogens and their effects on hosts cannot accurately be labelled as always being deleterious and harmful. Modern ecology has shown us that pathogens are key players in stable, robust ecosystems. They complicate community dynamics in beneficial ways, with trade-offs and consequences, limits and thresholds (9–11). Equally, evolutionary biologists understand pathogens to be critical

sources of selection pressures, important in driving evolution itself. In a very real sense, then, we are what we are, and our biosphere is what it is, because of disease (12–15). Generally, it also is true that, in nature, clinical disease on a large scale is unusual; disease epidemics are rare and aberrant events. They are noteworthy, most often, for this very reason. Thus, we should turn our standard view of disease on its head. When disease does occur in a large and major way in any species, we should think more often that the disease itself is probably not the most fundamental problem at hand, but is just one effect, one aberrational outcome, of some other more fundamental disturbance. This leads to my second conclusion.

2. Cause is complicated

In veterinary medicine, we take a very blinkered view of the causes of disease. We have not moved much beyond the late 19th Century paradigm of Koch and Pasteur. That paradigm is basically this:

$$(\text{Agent}) + (\text{Host}) = (\text{Disease})$$

In other words, disease results when you mix a host animal and a pathogen together. Within the Agent compartment of this model, we acknowledge a long and fascinating list of infectious and noninfectious pathogens. Within the Host compartment, our understanding of the complex pathophysiology of molecules and cell surface receptors, signals and responses, is the triumph of modern biomedical research. But our general notion of cause pretty well stops there.

This equation is grievously inadequate if we want to understand many of the really important diseases of our time, which becomes clear when we test this causal paradigm by applying it to an important disease, such as acquired immune deficiency syndrome (AIDS) and its associated *Human Immunodeficiency Virus(es)* (HIV):

$$(\text{HIV-1 or HIV-2}) + (\text{Person}) = (\text{AIDS})$$

This model is accurate as far as it goes, but it does not at all explain why AIDS emerged as a global epidemic only in the past few decades, with 40 million people quite suddenly infected worldwide and the number growing every year (16). A model of cause for the global AIDS epidemic, with greater power of explanation and which might provide a basis for interventions and resolution, would look something like Figure 1. This more complete model recognizes the origin of HIV-1 and HIV-2 from among the many known simian immunodeficiency viruses (SIVs), and the regular transmission of these among sympatric primate species, some of which result in infection. It recognizes that there have been multiple successful transmissions of these viruses to people, followed by adaptation and subsequent human-to-human transmission producing the various strains of HIV-1 and HIV-2. This model recognizes that the viruses, the people, and the other primates, the agents and the hosts, have existed together for thousands of years. The AIDS epidemic has been caused by new ecological and environmental factors, several of which have been listed (17,18). This is the notion of cause articulated by Stephen Lewis and others when they contemplate how the AIDS epidemic might be curtailed

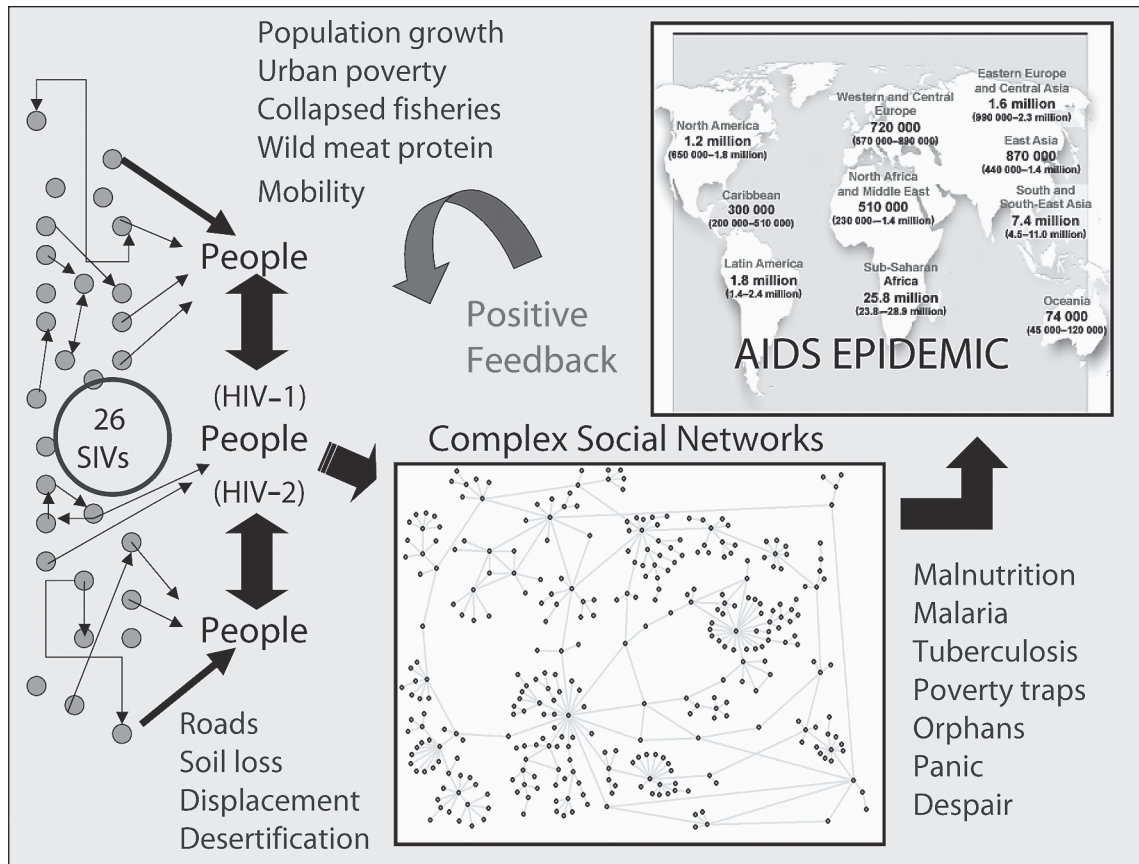


Figure 1. Disease in human or animal populations results from a complex array of interacting factors, as exemplified by this general model depicting the causes of the global epidemic of AIDS. Elements of this model are adapted from (16–18,51).

(19). It tells us that there are many points at which to attack the epidemic and reduce its impact. It tells us that drugs and condoms alone will not curtail this epidemic. It tells us also that we can expect an HIV-3 and an HIV-4 to arise from the same causal circumstances, if we do not change the ecological drivers of the AIDS epidemic. We need this more comprehensive and complicated view of what causes disease, if we are to avoid the worst consequences of the important disease issues of the 21st century.

3. Environment rules

Environment rules, in the sense that Britannia once ruled. When it comes to determining whether or not diseases will occur, or what the morbidity and mortality rates will be, environmental variables are the ones that most often have the determining influence. Another way of saying this is that the occurrence of disease very often is a signal of ecological or evolutionary maladaptation of animals and people to altered environments, which is only to acknowledge that evolution is busily at work in the biosphere, with phenotypes of all kinds adapting, or not, to changing selection pressures exerted by changing environmental circumstances. But in today's world of environmental changes on an unprecedented speed and scale, we must recognize complicated arrays of environmental changes as the fundamental causes of our really important disease problems.

Right now, when we teach veterinary medicine, we tend to give some passing mention to the presence of environmental factors among those that cause disease. Every student is told that the occurrence of disease is an interaction among the host, the agent, and the environment, but then we carry on as if only the interactions of host and agent really matter. Environmental factors, largely, are left aside, as if not really within the purview of veterinary medicine. This is a grave mistake, and one that ignores the most important causes of the most important diseases.

4. Treatment is possible

For the major disease issues associated with our global crisis, treatment is possible. If we accept that cause has many factors and that environmental factors often are predominant, we have a solid basis for anticipating that we really can take action to reduce the global burden of disease. We don't have to wait for new drugs or vaccines, or for some new advance in molecular science, helpful though these would be. If the past century has proven nothing else, it has proven that humans have enormous capacity to alter environments and ecosystems. However, our ecological understanding, at last, is catching up to our brute power. We are learning to think like a mountain. Our recognition that diseases are caused by many factors acting together means that we have many different options for interventions. We

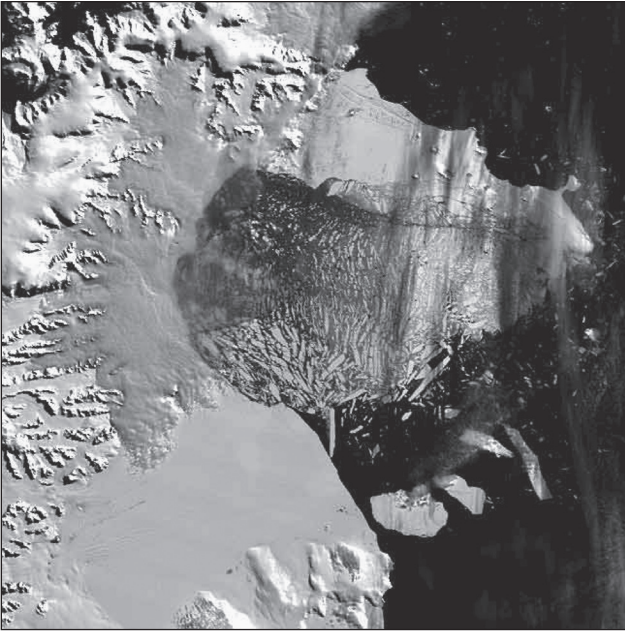


Figure 2. The Larsen B Ice Shelf of Antarctica photographed from space on 5 March 2002 during its final fragmentation. MODIS image courtesy of NASA's Terra satellite, and provided by National Snow and Ice Data Center, University of Colorado, Boulder, Colorado, USA.

also have new tools to work with: computing tools, remote sensing tools, mapping tools, social science tools, communication tools, genomics, and proteomics. There is nothing to prevent us from taking on the big disease problems of the world and solving many of them.

Veterinary medicine for our world in crisis

Let me now relate these 4 conclusions to the crisis I perceive our world to be in, and to the ways in which veterinary medicine can help get humankind through that crisis and out the other side. Our global crisis, fundamentally, is environmental and ecological. I think society has grasped the reality of our environmental crisis only in the past few years, mostly through evidence of global climate change and the strong scientific consensus as to its cause; namely, our monumental use of fossil fuels over the past 150 years. Images such as in Figure 2 have convinced us. The Larsen B ice shelf in Antarctica, an enormous mass of permanent sea ice, 3250 square kilometers in extent — the size of Luxembourg — melted away in a few short weeks in 2002, the result of a rise in the temperature of a mere 0.3°C in the surrounding Weddell Sea over the preceding 30 years. Glaciers previously held back by that ice shelf are now plunging into the sea at an alarming rate. The message is that the poles are melting and that sea levels will rise as a result, only a meter or so if we are quick to respond, tens of meters if we are not (20–22).

Climate change is only one element in the ecological crisis of the 21st century. Fresh water is in short supply worldwide. Much of global food production depends on irrigation from deep aquifers and these will soon be exhausted (23). Soil fertility is in severe decline, and soil erosion is occurring at 10 to 40 times the rate of soil formation (24–26). Most of the world's fisheries have collapsed, and much of aquaculture represents

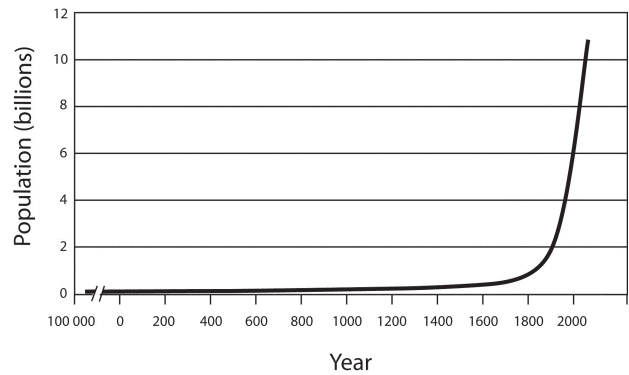


Figure 3. Global human population from approximately 100 000 BC to 2006AD and projected to 2050AD. Data are from references (30,31).

a net loss in fish protein (27,28). Humans currently make direct use of approximately 60% of the earth's total capacity for photosynthesis (26,29). The global forests, wetlands, and grasslands that supply the essential ecological services of oxygen production, carbon sequestration, water retention, soil fertility, and complex buffers against epidemic disease have been severely reduced (11,25).

We also know perfectly well why we are at this crisis point. Our current crisis has its origin in what the late Professor John Iversen of the WCVM used to call nature's "experiment with the big brain." This experiment has been running now for about 100 000 years. Figure 3 offers a graph of our numerical progress. It took us some 90 000 years to grow from a world population of perhaps 100 000 of the first *Homo sapiens* to about 5 million. Then we developed agricultural food production and, over the ensuing 9000 years, population doubling time went from 10s of thousands of years to a few hundred years. About 200 years ago, we discovered technologies to make use of fossil energy, and you can see the result. Our global population immediately began a rapid, exponential expansion. We are now 6.5 billion people on earth. The first billion was achieved in just over 100 000 years; the most recent billion was added in 12 years (30–32). Our use of energy has grown much faster even than our absolute numbers, about 20-fold since 1875, while our population has grown only about 4-fold (25). Now we risk being destroyed by our own success. Our thin green biosphere has become the ultimate case of the "Tragedy of the Commons" (33,34). We have had our eyes on the ground, pursuing our particular economic agendas across the globe, but we have not looked around to note our enormous impact on the systems that sustain us, until quite recently.

Our current unprecedented numbers and the unprecedented intensity of our activities are the driving force, the ultimate cause, of our current global crisis. So, Figure 3 carries a profound message for veterinary medicine. This sudden vertical rise in human numbers and activities signals enormous problems for human and animal health. It is paralleled by a rise in the global population of livestock to equally astounding and unprecedented numbers and densities, all over the world (35,36). It is also paralleled by the rising curve of emerging infectious diseases, mostly animal diseases and diseases transmissible from animals to people (11,37–40). These have made animal agriculture

Figure SDM1. HARMFUL EFFECTS OF ECOSYSTEM CHANGE ON HUMAN HEALTH

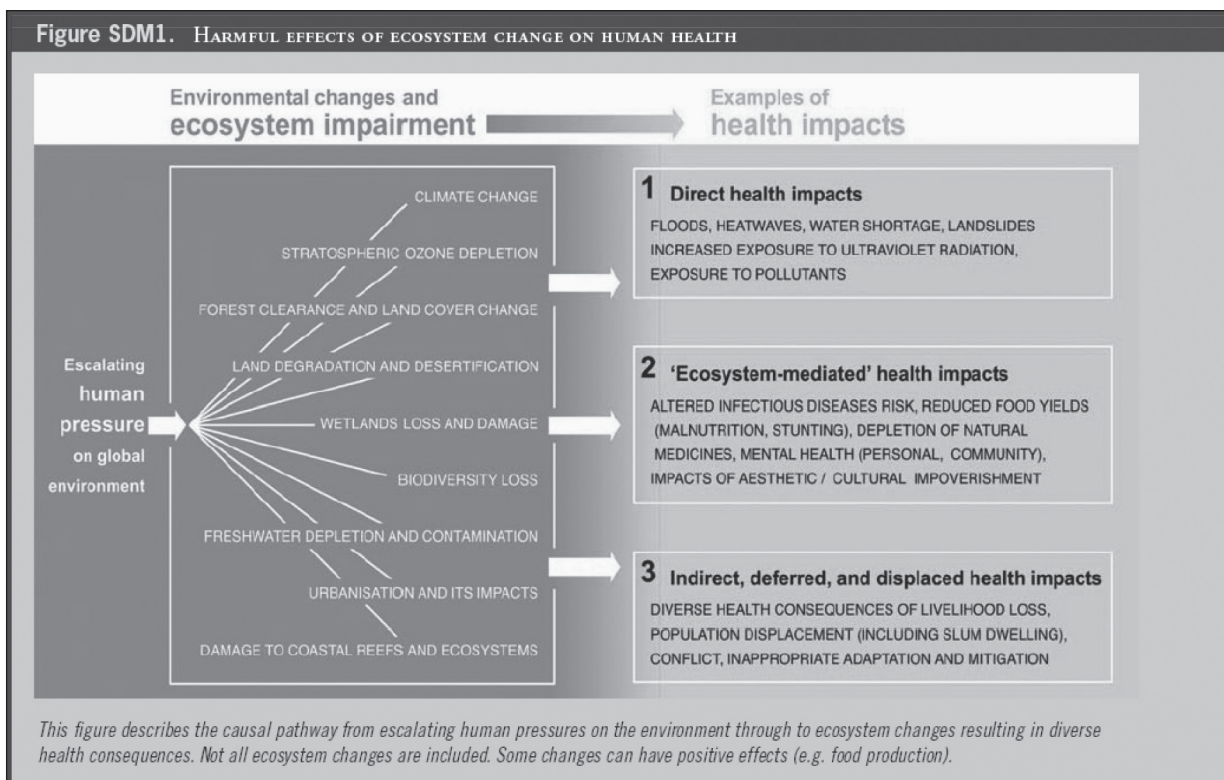


Figure 4. The cause of diseases in our current global crisis. From *Ecosystems and Human Well-Being: Health Synthesis. A Report of the Millennium Ecosystem Assessment* by Corvalan, Hales, and McMichael (49). Printed with kind permission from the World Health Organization.

difficult and expensive in many parts of the world (35,41). They have reduced the diversity and richness of the plants and animals that are the engines of our ecosystems and, hence, of our own survival, and they have imposed a huge new burden of disease on human society (11;42–44).

Apocalypse not

We are indeed at a moment of crisis but, not yet, of irreversible global disaster. Recognition of this crisis should galvanize us, not to despair, but to action. What the world needs is intelligent optimism and hard work. I think there is every reason to believe that “the experiment of the big brain” can turn out to be a success. There already are positive signs and developments. Human fertility rates are falling nearly worldwide (31). Recently, energy scientists have calculated that, with currently existing technologies, the United States could produce 98% of its total energy needs from renewable sources, mostly direct solar (45).

There are also historical precedents for human society making abrupt, radical changes in what it does. Consider, for example, our view of the safety of industrial chemicals. An international debate in the 1960s over the relative benefits and costs of the new and massive use of industrial chemicals, such as dichloro-diphenyl-trichlorethane (DDT), resulted in a complete reversal of public opinion about chemical safety and in the creation of government departments of the environment throughout the world in less than a decade (46). And consider the hole in the ozone layer. Within a decade of documenting that atmospheric

ozone was being destroyed by industrial chlorofluorocarbons, the Montreal Protocol to discontinue their use was signed into effect. In the subsequent 17 years, atmospheric concentrations of these chemicals have stabilized or decreased, and the amount of ozone in the upper atmosphere is slowly creeping upward again (47). So change, even radical social change requiring large economic adjustments, is possible and is part of our cultural history.

Moreover, there already are well conceived road maps to a sustainable future that do not require that humanity pass through massive epidemics, starvation, warfare, and social collapse. Our adaptation to the limits of the biosphere do not have to be Malthusian. In the year 2000, the United Nations initiated the Millennium Ecosystem Assessment, the world’s most comprehensive assessment ever of the current state of the biosphere (48). A major component of that Assessment was examination of the relationships between the functional states of ecosystems and the health and well-being of people within them. This included an exhaustive clinical and ecological diagnostic assessment of the causes of the world’s major disease problems. A summary of that examination is available free-of-charge (49). The Assessment’s diagnostic conclusions are presented in Figure 4. Escalating human pressures on the global environment are causing a myriad of serious disruptions to the function of the ecosystems that sustain us. These impairments of ecosystems are having substantial and diverse effects on human health, some direct, some indirect, and some mediated by the consequent and growing social strife.

1. Eradicate Extreme Poverty and Hunger
2. Achieve Universal Primary Education
3. Promote Gender Equality and Empower Women
4. Reduce Child Mortality
5. Improve Maternal Health
6. Combat HIV/AIDS, Malaria and Other Diseases
7. Ensure Environmental Sustainability
8. Develop a Global Partnership for Development

Figure 5. Prescription for a small planet: The Millennium Development Goals of the United Nations (49). Also available at <http://www.un.org/millenniumgoals/> Last accessed February 12, 2007.

Prescription for a small planet

The Millennium Ecosystem Assessment's diagnosis is followed by a detailed prescription for how to redress disease and to restore health. The prescribed treatment is to achieve 8 measurable goals (Figure 5), aimed squarely at the ultimate causes of our most important diseases. This prescription reverberates with the wisdom of Virchow and Leopold. It is a prescription of multiple, complicated cures for disease issues of multiple complicated causes, for which environmental factors are the predominant variables. This prescription has come to be called the United Nation's Millennium Development Goals, and they are no mere pipe dream. Each comes with a roadmap to achievability. None would cost as much to achieve as does one month of current global armed conflict. For example, economist Jeffrey Sachs insists that world poverty can be eliminated on a time scale of a few decades, and he is carrying out pilot projects to prove that this is so (50).

These are the treatments for our world crisis that veterinary medicine must help to deliver. There are essential applications for veterinary medicine in the achievement of all of these goals: to predict, prepare for, and manage the health consequences of inevitable environmental changes; to reduce health risks in the rising tide of zoonotic diseases; to find new ways to deliver animal health services at affordable cost, in remote areas, and without pharmaceutical excess; to excise people and their animals from the inhumane conditions of poverty; and to develop new and better drugs, vaccines, and other biologicals. There is no end of veterinary things to do, and no shortage of careers for eager and committed veterinarians.

I believe veterinarians are especially well suited to taking on the challenges of our global crisis. Our profession's mandate generally is to take action and fix things. We know the drill of careful examination of a problem, differential diagnosis of its particular causes, development of an evidence-based treatment strategy, and regular reassessment of a treatment's effect. This is an approach of enormous practical power, which can be applied in a thousand different ways to achieve the Millennium Development Goals. Jeffrey Sachs emphasizes that the medical paradigm of careful differential diagnosis, and treatments to match each different diagnosis, is key to solving complex soci-

etal problems, as much in economics as in medicine (50). Our ultimate goal must be to sustain both our civilization and the biosphere that sustains us while we pass through the peak in our global numbers and ecological footprint, probably in this century, and then subside to some smaller, truly sustainable level in the centuries ahead. This is what the Millennium Development Goals are intended to achieve.

Leadership

Veterinary students eager to confront the world's perils could be forgiven for thinking that they could, now, drop in at their college's Departments of Millennium Development Goal Achievement and Ecological Medicine to sign up for some relevant courses. Right now, there are no such departments and few such courses. They might write to their national or provincial veterinary associations for career advice, or to receive their profession's committee reports on its programs of veterinary interventions in global hunger and the AIDS epidemic. But, in all likelihood, the letters would be returned with polite notes suggesting that the students may have addressed their letters to the wrong organizations. Social leadership is not the strong suit of the veterinary profession just now. But there is hope. Even within our profession, change may be in the air, together with the rising concentration of carbon dioxide. Perhaps we need a symbolic moment to catalyze change and crystalize our own resolve. Here is a suggestion, perhaps recognizably from a baby-boomer who grew up in the heady 1960s.

Let us come together at the next convention of the Canadian Veterinary Medical Association (CVMA), conveniently being held in Ottawa in summer 2007. And there, let us erect a symbolic compost pile in which we will bury and decompose those odious glossy inserts advertising fuel-wasting luxury cars and other symbols of mistaken human excess, which arrive at our doors packaged with our national veterinary journal, as a signal from our profession that a higher order of environmental responsibility is now expected from its national organization. And beside that symbolic conversion of bad consumer practices to fertile soil, let us ask the whole convention to join us in a loud and raucous funeral service for the veterinary *status quo*. Let us then invite the CVMA to form some new committees to engage us visibly, collectively, and meaningfully with the crisis of the world. A committee on achievement of the Millennium Development Goals would be a good start, with perhaps another to track, inform the membership, and assure broad veterinary engagement in the major health issues facing Canada and the world.

We must volunteer to serve on these committees and organize plenary sessions on relevant topics for subsequent conventions. But then we must return to our veterinary colleges and nail the Millennium Development Goals to the front doors, and also to the doors of the admissions office, the curriculum committee, and the office of research. From what I can learn of Francis Schofield, I think he would have approved of such goings on, partly because they would create a terrific row, but also because they would underscore his conviction that veterinary medicine has an absolute ethical and social obligation to engage fully in the global issues that will determine our collective future.

And when we revise our veterinary curricula to meet our profession's newly accepted mandate to bring leadership and action to the navigation of our world through crisis, we must ensure that the inspiration of visionary leaders like Aldo Leopold and Rudolf Virchow are front and center. Students who would step forward to confront our global crisis must have the ecological savvy to "think like a mountain," and they must understand how an epidemic disease like typhus can be caused by poverty and cured by schools.

Acknowledgments

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