

Perspective: **Environment, Biodiversity, and the Education of the Physician of the Future**

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Abstract

Ours is an age of unprecedented levels of environmental alteration and biodiversity loss. Beyond the exposure to environmental hazards, conditions such as environmental degradation, biotic impoverishment, climate change, and the loss of ecosystem services create important health threats by changing the ecology of many pathogens and increasing the incidence and/or severity of certain noncommunicable conditions. They also threaten health in the future by weakening the Earth's life support systems.

Although physicians remain one of the most often accessed and most

trusted sources of information about the environment, there is currently little emphasis on educating medical professionals about these environmental issues. This lack of training reduces the ability of most physicians to be efficient science–public interfaces and makes them ineffective at contributing to address the fundamental causes of environmental problems or participate in substantive environmental policy discussions. This is an important challenge facing medical education today.

To turn medical students into effective physician–citizens, an already-

overwhelmed medical school curriculum must make way for a thoughtful exploration of environmental stressors and their impacts on human health. The overarching question before medical educators is how to develop the competencies, standards, and curricula for this educational endeavor. To this end, the authors highlight some of the critical linkages between health and the environment and suggest a subset of key practical issues that need to be addressed in order to create environmental education standards for the physician of the future.

Rudolf Virchow, one of the founding fathers of social medicine, emphasized the multifactorial origin of disease, wherein the interplay of social, political, and economic conditions was an important determinant of disease acquisition, manifestation, and

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consequence. His own life and writings exemplified his call for physicians to proactively influence the social determinants of health. As a way to consolidate our modern approaches to medicine, physicians and their professional organizations have begun to address not just disease but its social determinants, getting involved in cross-cutting issues because their impact on health and disease are significant.

Understanding the global environmental determinants of health is one of the major challenges in the 21st century and will require a similar shift in focus and the incorporation of transdisciplinary thinking from medical professionals. Human pressure on the Earth's ecosystems now extends over the majority of the planet's area and its energy flows and affects most of the world's terrestrial, freshwater, and marine environments.^{1–3} Our combined influence over global environmental conditions is relevant to the medical profession because sustaining human health ultimately depends on environmental sustainability,^{4,5} because severe environmental change has been shown to create specific health concerns,⁶ and because continued environmental degradation and biotic impoverishment can be considerable sources of health threats in the future.^{7,8}

Although physicians remain one of the most often accessed and most trusted sources of information about the environment,⁹ there is currently little emphasis on educating medical professionals about environmental issues beyond the management of exposure to environmental hazards. We believe that this is an important challenge facing medical education today. This article is a call to help equip physicians with the tools and knowledge they need to examine and hopefully mitigate the impact of climate change, environmental degradation, and the loss of biodiversity on the health of the human population. To turn medical students into more effective physician–citizens, an already-overwhelmed medical school curriculum must make way for a thoughtful exploration of environmental stressors and their impacts on human health. Here, we illuminate some of the issues connecting environmental degradation and human health and call for a broad discussion about best practices for achieving environmental literacy in the physicians of the future.

Environmental Degradation, Loss of Biodiversity, Climate Change, and Human Health

We live in an age of unprecedented levels of environmental alteration. Recent

research has shown that the drivers of environmental degradation can create considerable costs in terms of human health and well-being. Although physicians are acutely aware of the contribution of stressors such as radiation, air and water pollution, and access to sanitation to the global disease burden,^{10,11} other forms of environmental change, about which physicians are often much less educated, can also result in significant health threats. For example, land use changes such as urbanization, deforestation, and habitat fragmentation can increase infection risk by creating ecological conditions that result in high transmission intensity. This occurs by alterations of the distribution of human populations in relation to nonhuman pathogen hosts, by increasing the abundance of nonhuman reservoir hosts, or by changing the distribution and/or the behavior of insect vectors.^{12–14} Other human activities have been shown to have important, and often negative, consequences on the ecology of infectious agents—for example, by increasing the frequency of contact among hosts (e.g., wildlife trade and consumption), or by favoring novel associations between humans, domestic animals, and wildlife (e.g., habitat encroachment and fragmentation).^{15,16} These forms of anthropogenic environmental change have been identified as being associated with pathogen emergence or reemergence in humans, as well as in other taxa.^{17–19} Through affecting air quality and increasing ambient temperature (e.g., in urban heat bubbles or via the effects of global climate change), environmental alteration can also increase the incidence and/or severity of noncommunicable conditions including allergies, asthma, and heat stress.^{20–22}

Biotic impoverishment can also translate into threats to human health.^{7,8} Recent research has found that higher diversity of species can buffer the transmission of, among others, the Lyme disease spirochete and West Nile and Hanta virus strains.^{23–25} Other studies have provided empirical and theoretical evidence suggesting that diverse ecosystems are associated with lower parasite infestations and lower densities of disease reservoirs,^{26,27} and there is evidence that habitat conservation can provide natural buffers and lower mortality in the face of natural disasters.²⁸

Available evidence suggests that climate change can result in changes in the distribution ranges, length of the transmission season, and life cycles of disease vectors, thereby increasing their transmission intensity.^{29–31} Additionally, climate changes are expected to have noninfectious health effects by exacerbating exposure to extreme temperatures and by increasing the severity and frequency of extreme weather events.⁶ Importantly, future projections of climate change can be expected to increase these health risks.⁶

At the same time, an ever-increasing body of evidence suggests that there are many important physical and mental health benefits derived from contact with nature. Research suggests that contact with and/or proximity to green spaces can accelerate surgical recovery,³² reduce pain,³³ reduce aggression and lower mental fatigue,³⁴ support attentional function,^{35,36} and increase longevity.³⁷ Further, a recent study found lower rates of circulatory and all-cause mortality in people living in areas that grant them greater access to green spaces, and that health inequalities related to differential earning power are lower in the same areas.³⁸ Access to undeveloped areas with natural vegetation may thus affect health and health-related behaviors (e.g., by providing opportunities for stress reduction and physical exercise), allowing economically disadvantaged populations to enjoy health benefits on par with those with higher incomes.³⁸

It is not just the world we live in but also the potential it holds that is at risk. Environmental destruction eliminates natural medicinal repositories and medical models, thereby limiting the frontiers of discovery in science and medicine.^{39,40} The loss of agricultural diversity and its associated cultural systems threaten food security and nutrition, especially in the developing world.^{41–43} Ecosystem services such as pollination, nutrient cycling, and waste removal contribute to the normal functioning of ecosystems and, therefore, the maintenance of livable environments. These basic support systems are rapidly diminishing.

The threats created by broad environmental degradation are often difficult to quantify, predict, and address.⁴⁴ For example, it is still

challenging to accurately assess the magnitude of the indirect effects of biodiversity loss on water potability and food security, yet these factors are likely to have some of the greatest effects on global health.⁴⁵ Further complicating this scenario, the impact of environmental change cannot be expected to act in isolation: populations already deemed vulnerable through extreme poverty, geographic susceptibility, or poor governance will bear a disproportionate burden of the consequences of environmental degradation through further displacement, forced migration, and worsening disenfranchisement and impoverishment.⁴⁶

We can thus assume that global environmental change will have important health costs, that it will threaten our capacity to sustain the planet's basic support systems, that these costs will tend to increase, and that they will primarily affect, at least initially, populations with less means with which to escape them. Herein is a critical challenge for medical professionals and for society at large. Although many of these forms of environmental change are the drivers of the economic growth responsible for important societal gains in health and well-being, they are simultaneously important causes of health threats. Quantifying the magnitude of these threats remains an elusive goal in determining a thoughtful balancing of societal priorities and courses of action.

The Physician and the Environment: A Duty to Educate

Although environmental degradation and biodiversity loss pose important threats to our ability to sustain human health, physicians are rarely trained to understand, act on, or inform the public about these issues. This lack of training reduces the ability of most physicians to be efficient science–public interfaces and makes them ineffective contributors in addressing the fundamental causes of environmental problems or participants in substantive environmental policy discussions. However, physicians are educators and respected interlocutors. They are society's go-betweens, routinely translating abstract medical science into evidence-based treatment plans. The doctor–patient relationship is singularly cherished, and physicians hold the public

trust. The opportunity to educate society on such profound and widespread health risks should not be overlooked. To help frame discussion on these difficult issues in terms of human health will allow for a more grounded dialogue. Health is a powerful motivator, and research in social science has shown that risks identified in terms of human life are much more effective fulcrums for change than abstract concepts.⁴⁷

There have increasingly been calls within medicine for physicians to play a greater role in these discussions.^{48–50} There are numerous instances where physicians have played a significant role in implementing local policies and actions regarding environmental change—for example, encouraging mosquito-proofing of houses while advocating for an invigoration of epidemiology and outbreak surveillance.⁵¹ In the United States, the American Medical Association (AMA) has likewise weighed in—for example, by explicitly endorsing the findings of the Intergovernmental Panel on Climate Change.⁵² This resolution included the following statements:

[The AMA will] support educating the medical community on the potential adverse public health effects of global climate change and incorporating the health implications of climate change into the spectrum of medical education.

[The AMA will] recognize the importance of physician involvement in policymaking ... [and] support efforts to search for novel, comprehensive approaches to mitigating climate change to protect the health of the public

[The AMA will] encourage physicians to assist in educating patients and the public on environmentally sustainable practices, and to serve as role models for promoting environmental sustainability.

This is a formidable mandate, and it raises the question: How should physicians educate themselves to fulfill these roles? We believe that the environmental literacy of the physician of the future is necessary and aligned with recommendations in the recent landmark report of the Carnegie Foundation for the Advancement of Teaching on Medical Education, which highlighted the need for “exploration of the role of physician–citizen.”⁵³ Because a healthy society depends on functioning ecosystems and a stable climate, we infer that it is the duty of physicians to be educated in these issues and to share this

knowledge with their patients through skillful advocacy and public leadership.

To informally gauge the extent to which environmental alteration is currently integrated into medical curricula in the United States, in May 2011 we searched the Web sites of the 150 member medical colleges of the Association of American Medical Colleges for course content. We determined that environmental education is not included in the already-crowded medical school core curricula in the United States. American medical students interested in environmental issues must generally seek elective courses during their third and fourth years through affiliated graduate-level global health or public health institutions or via a self-structured research elective with the selection of an appropriate mentor. When available, these courses might come at an additional cost to students. However, several examples suggest that integration of environmental education in medical school is feasible. Yale Medical School allows medical students to enroll in environmental health classes, Harvard Medical School’s Center for Health and the Global Environment offers formal training on the relationship between health and environmental change, and the Wilderness Medical Society offers a list of electives available through national parks, outdoor leadership institutes, and medical schools throughout the United States.⁵⁴ Since spring 2010, the Weill Cornell Medical College in New York has partnered with the Center for Biodiversity and Conservation of the American Museum of Natural History and the Sackler Institute for Comparative Genomics to offer a semiannual, half-day multidisciplinary lecture series to medical students. Topics of the series include basic concepts about the relationship between biodiversity, environmental change, and health, and the relevance of molecular ecology to biomedical research and medical practice.

Linkages between health and other disciplines and policy areas, such as the economy, ecology and conservation biology,^{55,56} and veterinary education and practice,⁵⁷ have already been proposed. In addition, educational resources on environment and health exist outside medical schools, allowing for physicians and professionals from other scientific disciplines to interact and develop innovative solutions to our common

environmental and health problems. For example, the Network for Conservation Educators and Practitioners and the Center for Biodiversity and Conservation at the American Museum of Natural History offer open-access materials on biodiversity, the environment, and health, which can be integrated into existing courses or used as independent study tools.^{58,59} Other natural history museums, botanical gardens, and conservation organizations are currently involved in research, education, and outreach activities that are directly applicable to these efforts.

In some cases, these research and outreach programs include training specifically tailored for physicians.⁶⁰ The Center for Sustainability and the Global Environment at the University of Wisconsin–Madison offers a variety of educational opportunities, from individual seminars and courses to fellowships and graduate studies, available to public health and medical students.⁶¹ The World Health Organization offers information and training on global environmental and climate change.⁶² The Global Health Education Consortium offers Web-based modules and other open-access educational resources.⁶³ Additionally, the kinds of transdisciplinary discussions necessary to bring together the fields of ecology, conservation biology, evolution, environmental science, and the medical sciences have been explored in detail in the scientific literature.^{56,64,65} This includes peer-reviewed scientific journals dedicated to exploring these issues (e.g., *EcoHealth and Environmental Health Perspectives*) and several others that regularly publish work relevant to these discussions.

Medical Education and the Environment: Future Directions

The overarching question before medical educators is how to practically develop physicians who carry enough knowledge about the environmental determinants of health to fruitfully participate in public debate and serve as public educators. We believe that we need to answer several key questions about environmental education: What are the minimal environmental competencies we desire in the physician of the future? What are the most efficient formats in which to offer training to fulfill these competencies?

Who is best suited to lead this effort: medical schools, graduate training programs, or medical specialty societies? What would a curriculum look like, and who would teach the varied components?

In addition to adding academic content in medical education, we suggest that physicians need to develop a skill set beyond that of the doctor–patient relationship, one that is geared toward engaging the broader public health and health policy community. To be effective societal translators of environmental science, physicians should be able to expound not only on the quality of the information that reaches the general public but also on its associated pattern (i.e., interpretation of environmental phenomena) and process (i.e., the intellectual pathways of scientific consensus).

We believe that any comprehensive medical school syllabus on the study of health and environmental change will require input from medical practitioners, public health professionals, environmental scientists, ecologists, and policy experts. This will require physicians to embrace multi- and transdisciplinary work alongside professionals from many backgrounds. Working in collaborations in fields such as ecology, public health, and governmental service presents promising opportunities for forming coalitions and acquiring mentorship, as well as for physicians to develop greater fluency in the language of these affiliated fields. Such interprofessional training will be critical to this effort.

Fortunately, in nearly every area of environmental health there already exist organizations and professional bodies with extensive multidisciplinary educational programs. This collective experience should not be overlooked, and educators would be wise to consider these groups as a starting point for curriculum creation. Across the United States, for example, governmental, nongovernmental, and private institutions could become meaningful contributors to such a collaboration. Beside the organizations already mentioned, some examples are the Centers for Disease Control and Prevention, the One Health Initiative, Environment America, the EcoHealth Alliance, and the Consortium for

Conservation Medicine. Acknowledging the herculean effort it would take to bring such diverse stakeholders to the table, we nevertheless reiterate the urgent need to act.

We propose a slow but determined march forward: a dialogue of scholars and experts from the above fields to identify and advocate topics that their respective disciplines deem critical to medical education. We envision a continued dialogue in the academic medicine community leading to coordinated learning goals, curricula, resources, and best practices. An open-access repository of these discussions and materials has the potential to provide educational opportunities to the physician of the future anywhere in the world.

The end point is equipping tomorrow's physician–citizens with the skill sets to be credible voices in the environmental change dialogue. To this end, we ask that interested parties contact the corresponding author for the goal of forming a working group. This group, in turn, would be charged with coalescing the themes that stakeholders agree would be critical to a medical school core competency curriculum. We envision this working group as a first step in developing programs for the education of physicians about these issues, thereby empowering them to contribute to environmental sustainability and the provision of sustainable public health. Far from being training in environmental advocacy, we suggest that this exposure will prepare physicians to develop informed and reasoned stands on environmental issues, including the uncertainties in our current knowledge,^{66,67} and the many complex normative issues linking consumption, reproduction, standards of living, and health.^{11,68} We believe that this is a critical component in the education of the physician–citizen of the future.

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