Addressing Climate Change and Its Effects on Human Health: A Call to Action for Medical Schools

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Abstract

Human health is increasingly threatened by rapid and widespread changes in the environment and climate, including rising temperatures, air and water pollution, disease vector migration, floods, and droughts. In the United States, many medical schools, the American Medical Association, and the National Academy of Sciences have published calls for physicians and physicians-in-training to develop a basic knowledge of the science of climate change and an awareness of the associated health risks. The authors—all medical students and educators—argue for the expeditious redesign of medical school curricula to teach students to recognize, diagnose, and treat the many health conditions exacerbated by climate change as well as understand public health issues. In this Invited Commentary, the authors briefly review the health impacts of climate change, examine current climate change course offerings and proposals, and describe the rationale for promptly and comprehensively including climate science education in medical school curricula. Efforts in training physicians now will benefit those physicians’ communities whose health will be impacted by a period of remarkable climate change. The bottom line is that the health effects of climate reality cannot be ignored, and people everywhere must adapt as quickly as possible.

In 2019, an international multidisciplinary *Lancet* collaboration concluded that climate change poses unacceptable threats to the health of current and future populations worldwide. Extreme weather events, rising temperatures, flooding, droughts, air pollution, and wildfires are steadily increasing around the world. Climate change is among the greatest public health threats of the 21st century and a defining modifier of the global burden of disease. The World Health Organization (WHO) projects there will be approximately 250,000 deaths annually from climate change worldwide between 2030 and 2050. The direct effects of climate change are both obvious and insidious, leading to acute and chronic diseases that result from increased temperatures, food and water insecurity, air pollution, and vector-borne diseases. The poor and disenfranchised are affected disproportionately by climate change, with conflict and mass migration stemming from hostile environmental conditions.

**The Problem: How Climate Change Affects Human Health**

The largest geophysical global climate change is the steady rise in temperatures worldwide. Global temperature rise is driven primarily by combustion of fossil fuels and deposition of greenhouse gases in the atmosphere at a rate that exceeds natural processes. Without immediate mitigation efforts by major industrialized nations, the morbidity from rising temperatures will be difficult to prevent. Even small changes in temperature and precipitation result in large changes in disease transmission and serious chronic illnesses. Children, low-income families, individuals with preexisting conditions, pregnant women, and the elderly are the most susceptible to the health effects of increased heat. Pregnant women are particularly vulnerable to ambient heat, as rising temperatures may have a direct effect on human gestational time, increasing the risk of premature birth and birth defects. Importantly, the number of people exposed to annual heat waves is growing: Globally in 2018, 220 million people were exposed to annual heat waves, far above previous records.

Related to temperature increases are extremes of precipitation and the intensity of storms. Rising temperatures contribute to the spread of vector-borne and water-borne diseases and lead to the growth of fungi and molds that increase respiratory and asthma-related illnesses. While rainfall increases dramatically in some regions of the world, long-term droughts occur elsewhere. Droughts can increase the risk of vector-borne diseases spread by container-breeding mosquitoes in communities without safe, reliable access to water. Droughts reduce yields and nutritive value of crops, contributing to food insecurity, malnutrition, starvation, and mass migration. Climate change is also inextricably linked to ambient air pollution, a leading global risk factor for premature death. For instance, warming temperatures exacerbate production of key pollutants such as ozone, and climate-driven increases in fuel aridity have driven large increases in wildfires across the United States and around the world, undoing decades of air pollution improvements.

Proposed climate change mitigation policies—particularly policies intended to transition us toward cleaner energy sources in electricity production and transportation—would likely have large air quality benefits. Resulting changes in air quality would substantially affect a range of health outcomes. Breathing polluted air damages the heart, lungs, and other vital organs, contributing to
Exposure to ambient air pollution, most notably fine particulate matter < 2.5 µm (PM$_{2.5}$), leads to diseases such as stroke, heart disease, lung cancer, asthma, chronic obstructive pulmonary disease, and respiratory infections. The WHO estimates that 7 million people die annually from exposure to air pollution, making it the largest global environmental risk factor for premature mortality. An estimated 4.2 million pediatric deaths around the world are linked to ambient air pollution, and more than 90% of the world's children are exposed to high levels of PM$_{2.5}$. Air pollution and heat have also been linked to low birth weight, preterm birth, infant mortality, congenital cataracts, neural tube defects, and increased birth rates on days hotter than 90°F.

In 2017, approximately 22 million people around the world were forced to leave their homes because of "sudden onset" weather events such as flooding, forest fires, droughts, and intensified storms. The Brookings Institution projects that populations in Latin America, sub-Saharan Africa, and Southeast Asia will generate 143 million more climate migrants by 2050 than they did in 2019. Climate change is also contributing to slower-onset environmental shifts that can force human migration, such as desertification, sea-level rise, ocean acidification, air pollution, rain pattern shifts, and loss of biodiversity. Enlarging refugee camps have high rates of diarrheal diseases, measles, acute respiratory infections, malaria and other vector-borne diseases, sexually transmitted infections, malnutrition, and chronic disease complications.

Climate change also increases mental health disorders due to weather disasters, forced migration, food insecurity, and extreme heat waves. Posttraumatic stress disorder, depression, domestic abuse, general anxiety, and substance abuse have all been associated with climate change in some contexts. In the United States, the numbers of deaths and emergency department visits for mental health emergencies have been associated with periods of high ambient temperatures, as have the rates of suicides and domestic violence.

Finally, it is important to recognize that hospitals and laboratories emit 4.4% of the world's greenhouse gases and are responsible for more than 5 million tons of waste each year. Medical schools and trainees help lead the effort to reduce this pollution. Many institutions have launched environmental initiatives, from energy conservation to green lab programs. In December 2018, 7 Boston-area teaching hospitals and clinical institutes, including Harvard Medical School, announced a commitment to decarbonize. The University of California system has pledged to become 100% reliant on clean electricity for its campuses and medical centers by 2025, and the Cleveland Clinic is working to become carbon neutral by 2027. Numerous hospitals, including the Columbia University Medical Center and Shands Cancer Hospital at the University of Florida, have received LEED certifications.

The Training Gap: Climate Change and Medical Education

Given the potential burden of diseases related to climate change, medical trainees must learn to recognize, treat, and prevent climate-related health conditions in their patients. The global pandemic of COVID-19 has starkly demonstrated that society and physicians must be ready to deal with sudden health-related events. Though more insidious in general, climate change already produces extreme weather events that need prepared health care systems. Physicians should be trained to work on mitigation, adaptation, and policy making around climate change. Studies show, however, that most students and physicians in practice lack the necessary knowledge and skills to do so. Despite this training gap, climate change is not an educational priority at most U.S. medical schools. In 2018, an Association of American Medical Colleges survey of 147 medical schools found that only one-third included any climate education in their curricula. The WHO, the American Medical Association (AMA), and the National Academy of Sciences each have published calls for physicians and physicians-in-training to develop a basic knowledge of the science of climate change and an awareness of the associated health risks. The AMA, at its June 2019 meeting, pledged the organization to promote education for medical students and physicians on the health threats from climate change. It specifies that curricula should prepare medical students, residents, and clinicians to have "a basic knowledge of the science of climate change, can describe the risks that climate change poses to human health, and to counsel patients on how to protect themselves from the health risks posed by climate change." Despite these calls for new curricula, most U.S. medical schools still offer little to no education on the health impacts of climate change.

The most compelling demands for climate change education come from medical students themselves, as they anticipate the uncertainties of future practice in a rapidly changing world. To this end, students organized a national alliance, Medical Students for a Sustainable Future (MS4SF.org), to address the need for climate education in U.S. medical schools. Similarly, medical students in Australia and Germany are pursuing related curricular reform. At Stanford University School of Medicine, medical students (A.G., J.G.) requested, codesigned, and helped to implement a new elective course in 2020, entitled The Impact of Climate Change on Human Health. The course examines the intersection of climate change and population health, pediatrics, women's health, psychiatry, infectious disease, and disaster management, along with advocacy and the greening of health care. Students from across the university have enrolled in the course.

Like Stanford, those U.S. medical schools that offer climate education generally do so through elective and seminar courses. As the momentum and successes of these courses increase, so will the demand for a more comprehensive approach to training, with climate science integrated into pertinent preclinical and clinical experiences. We anticipate increased demand for climate education across the continuum of medical training, including postgraduate and continuing medical education activities.

Several U.S. medical schools are early adopters of climate science education in their preclinical curriculum (Table 1). The University of Minnesota Medical School in Minneapolis, the Carle Illinois College of Medicine at the University of Illinois at Urbana-Champaign, and the Icahn School of Medicine at Mount Sinai recently added some climate change-related content to their curricula. At Icahn, for example, first-year students...
are offered an elective, 1-week seminar course on climate change as part of a global health module.\textsuperscript{15} Georgetown University School of Medicine provides a series of educational modules for medical students to explore the connections between air pollution and climate change, allowing them to identify sources of lung irritants, examine air quality data throughout the world, and offer patient care recommendations for relevant conditions. One of the most comprehensive programs is at the University of California, San Francisco, School of Medicine (UCSF), where first- and second-year medical students receive core lectures on climate and health and have the option to do a deeper dive through an inquiry immersion course. UCSF students are also exposed to climate change education through the UCSF Program for Reproductive Health and the Environment, and they can take a 10-week elective similar to the course at Stanford. Arianne Teherani, a research faculty member in the Office of Research and Development in the Department of Emergency Medicine at UCSF, is currently developing a comprehensive curriculum for educating students on environmental sustainability and health and is bringing together faculty and staff to form an interdisciplinary community of educators at UCSF.\textsuperscript{40,42} Longitudinal, integrated climate change curricula are also under consideration by several institutions.\textsuperscript{34,36,40,43,44} Students and residents should be taught how climate change affects different medical specialties, ranging from disease and organ systems to disaster preparedness and supply shortages. UCSF and Georgetown are planning to implement an interesting addition to clerkship education: Students rotating through clinics/offices would undertake projects to improve sustainability practices in health care and educate patients about climate change. Additionally, the Department of Emergency Medicine at the University of Colorado Anschutz Medical Campus sponsors a successful 2-year fellowship, Climate and Health Science Policy for physicians.\textsuperscript{29} For physicians already in practice, Yale University School of Medicine offers a continuing education certificate related to climate change.

### A Call to Action for Medical Schools

The Earth’s climate is changing rapidly, and the manifestations of these changes

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**Abbreviations:** MS1, medical school year 1; MS2, medical school year 2; MS3, medical school year 3; MS4, medical school year 4.

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<thead>
<tr>
<th>Institution</th>
<th>Course structure</th>
<th>Curriculum content</th>
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<tbody>
<tr>
<td>Warren Alpert Medical School of Brown University</td>
<td>Preclinical 10-week elective</td>
<td>Identifying and addressing emerging health concerns in the era of climate change</td>
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<tr>
<td>Emory University School of Medicine</td>
<td>MS3 and MS4 4-week elective</td>
<td>Course title: Climate crisis and clinical medicine</td>
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<td>• Climate change and emerging clinical challenges</td>
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<td>• Health equity and social justice</td>
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<td>• Climate solutions for the health care sector</td>
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<td>• Communicating about climate change</td>
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<tr>
<td>Georgetown University School of Medicine</td>
<td>MS1 and MS3 modules</td>
<td>Linking environmental health, climate change, air pollution, and respiratory disease</td>
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<tr>
<td>Mount Sinai Icahn School of Medicine</td>
<td>MS1 1-week elective</td>
<td>Seminar on climate change and global health</td>
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<tr>
<td>Penn State College of Medicine</td>
<td>MS4 2-week elective</td>
<td>Course title: Climate change, health, healthcare delivery, and sustainability</td>
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<tr>
<td>Stanford University School of Medicine</td>
<td>MS1 and MS2 10-week elective</td>
<td>Course title: The impact of climate change on human health</td>
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<td></td>
<td>• Links between the environmental effects of climate change and human health</td>
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<td>• How climate change shapes health care delivery</td>
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<td>• Applying principles of sustainability and environmental health counseling to clinical practice</td>
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<td>• Counteracting the environmental effects of climate change</td>
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<tr>
<td>University of California, San Francisco, School of Medicine</td>
<td>MS1 and MS2 preclinical core lectures</td>
<td>Climate change and health</td>
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<td>MS1 10-week elective</td>
<td>Course title: Earth Health</td>
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<td>• Climate Science and Terminology, Health Effects of Environmental Degradation &amp; Climate Change</td>
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<td>• Mental Health, and Infectious Diseases</td>
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<td>• Science, Capitalism, and Denial and the Environment &amp; Climate Change</td>
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<td>MS1 2-week course</td>
<td>Course title: Inquiry Immersion Course</td>
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<td>• Deep dive into how climate change impacts health, as well as how the health care system impacts the environment</td>
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<td>MS1 10-week elective</td>
<td>Course title: Reproductive Health and the Environment</td>
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<td>• Impact of climate change on women’s health</td>
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<td>• Environmental contaminants and reproductive health</td>
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<td>• Clinical practices</td>
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**Table 1 Examples of Climate Change Education in U.S. Medical Schools**
are likely to intensify. We can no longer ignore the direct and indirect effects of these changes on human health. The next generation of physicians must be better prepared to address the many implications of climate change on the mental and physical health of their patients and society. Physicians can play a crucial role in climate change mitigation and health system adaptation to prepare for emerging health threats. Despite compelling climate science, the greatest pressure for curricular change comes from medical students who fear graduating with little or no knowledge in this domain. Medical schools are responding to student demands, but slowly. The slow response to threats of climate change by the international community should not be mirrored in medical education. We believe there is an urgent need for broad, multidisciplinary climate science education for physicians, ideally integrated within each pertinent course or program of study, across the continuum of medical training. Efforts invested in physician training now will benefit their communities—generations of patients—whose health will be impacted by a period of remarkable climate change.

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Invited Commentary

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