

The Unique Role of Medical Students in Catalyzing Climate Change Education

Benjamin M Rabin^{1*}, Emaline B Laney^{1*} and Rebecca P Philipsborn²

¹Emory University, Atlanta, GA, USA. ²Department of Pediatrics, Emory University, Atlanta, GA, USA.

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ABSTRACT: Climate change is a well-recognized threat to human health with impacts on every organ system and with implications for disease processes across subspecialties. Climate-driven environmental exposures influence the pathophysiologic underpinnings of disease emphasized in the pre-clinical years of medical school. While medical schools are beginning to offer climate change and health electives, medical education is lagging in providing fundamental climate-and-health content to adequately prepare the next generation of physicians for the challenges that they will face in the provision of healthcare and the prevention and treatment of disease. This perspective piece highlights the unique role of medical students in catalyzing the incorporation of climate content into the pre-clinical medical school curriculum and provides topics for disseminated curricular integration with the concepts emphasized in the pre-clinical years of medical education.

KEYWORDS: Climate change, medical education, curriculum, planetary health, environmental health, students

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CORRESPONDING AUTHOR: Rebecca P Philipsborn, Department of Pediatrics, Emory University, 49 Jesse Hill Jr. Dr. SE, 2nd Floor, Atlanta, GA 30303, USA. Email: rpass@emory.edu

Introduction

As medical students interrupted in our clerkship year by a global pandemic of zoonotic origins, we were forced to reflect on a rapidly changing clinical landscape. Long before COVID-19, the World Health Organization (WHO) declared climate change the greatest threat to human health in the 21st century.¹ Last year's *Lancet Countdown on Health and Climate Change* starkly warned, "Without accelerated intervention, this new era will come to define the health of people at every stage of their lives."² Climate-driven harms to human health and efforts to adapt to climate change are increasingly permeating aspects of patient care—from a clinician's diagnostic index, to hospital supply chains and infrastructure, to environmental and racial inequities, to ethics and safety. While resonant in the COVID-19 era of health care delivery, these topics have been noticeably absent in medical education.

We and other medical students are distressed by the overwhelming challenges facing our planet and profession in conjunction with the short timeline to reverse course and safeguard human health from climate change. In a 2018 survey of Chinese medical students, nearly 90% agreed that climate change will have serious and negative impacts on human health globally and locally.³ The daunting challenges that climate change poses to public health are well-documented.⁴ Increasingly frequent and severe natural disasters disrupt healthcare, lives, and livelihoods, while more insidious effects of climate change pose risks to nearly every organ system.^{5,6} These exposures disproportionately harm those already vulnerable because of existing health

conditions and those already disadvantaged by structural racism and inequality.

Within our own pre-clinical curriculum, we heard no reference to the threat multiplier climate change represents to the diseases we learn about and will be expected to treat. Where or when, we asked, will we learn the pathophysiology underpinning climate-related exposures and illnesses? How will we recognize and manage the burden of climate-related mental health trauma—on both ourselves and our patients—food-insecure communities, or spread of vector-borne and emerging infectious diseases if we do not learn about these threats? Addressing climate change requires mobilization of doctors and education of medical students to act on structural determinants of health⁷—efforts that students, themselves, are embracing and leading.

Calls for Medical Education to Adapt to Our Climate Reality

A growing number of physicians have called for more robust medical education on the implications of climate change on health.^{8,9} A 2018 commissioned report of the Accreditation Council for Graduate Medical Education (ACGME) identified "climate-change medicine" as an emerging internal medicine subspecialty by 2035.¹⁰ The American Medical Association (AMA) echoed this position with a June 2019 policy resolution to support "climate change education across the medical education continuum," starting with undergraduate training.¹¹ Less than a month later, the United Nations declared a "climate emergency," and in partnership with over 7000 institutions across 6 continents, committed to strengthening climate change education.¹² In August 2019, the *New England Journal*

*Equal contribution.



of *Medicine* launched an online “Climate Crisis and Health” hub to help “mobilize the urgent, large-scale climate action required to protect health.”⁶

A handful of medical schools have answered these calls by introducing courses in sustainability and climate change.¹³ But so far, these courses represent exceptions. In a recent international survey of 160 institutional members of the Global Consortium on Climate Change and Health Education, only 15 respondents represented medical schools.¹⁴ In the United States, “climate change” remains absent from the Association of American Medical College’s (AAMC’s) Curriculum Inventory topic list of required and elective courses.¹⁵ The reality of current medical education does not reflect the vocal calls of medical professional societies for climate action.

Medical Students: Future Doctors and Current Climate Leaders

As future front-line workers in the climate crisis, students are uniquely positioned to advocate training in climate change and medicine. Recognizing a gap in our own pre-clinical education, we proposed a disseminated “Climate Change & Environmental Health” curriculum for the pre-clinical years at our medical school that has been endorsed by our Executive Curriculum Committee. We are now working alongside the director of the pre-clinical years curriculum and individual faculty to implement the proposal for current first year medical students, the class of 2024. While strategies for integration of climate and health content into curricula will vary by institution, our curricular objectives and approach are broadly applicable and potentially replicable at other schools. Our lessons learned may empower our fellow students to lead integration of climate and health education at their institutions.

Our engagement with climate and medicine began by forging partnerships with other students highly motivated to lead change and identifying a faculty mentor with expertise in climate and health (Box 1). Galvanized by our mentor’s early support, we organized a lunchtime interdisciplinary panel on Climate and Health at the School of Medicine. The panel discussion revealed enormous enthusiasm and desire for comprehensive teaching on this topic. Inspired to expand the 1 hour-long discussion into a series, we dove further into the existing literature to identify additional topics for discussion. We found that much of what we were already learning in class—like the drivers and dependencies of cardiovascular and renal pathophysiology—are linked to climate change.

We looked for other examples of curricula on climate change in medical education. While workshops abroad have called for environmentally accountable curricula for the medical profession and outlined helpful curricular frameworks, suggested learning objectives provide broad themes rather than specific linkages of climate change to healthy human physiology and disease emphasized in the first 2 years of medical school.¹⁶ We

Box 1. Steps for medical students to adapt locally to develop and gain institutional support for a climate change and environmental health curriculum in the pre-clinical years.

- **Identify highly motivated student-leaders in climate and environmental health**
- **Identify faculty mentor(s) with climate and health expertise**
- **Organize interdisciplinary panel or talk for students**
- **Research existing climate and health resources**
- **Identify linkages to climate and health content in existing curriculum (real-time)**
- **Meet with senior faculty members to discuss curriculum feasibility**
- **Outline curriculum proposal including fraction of time for proposed climate and health content as a proportion of total classroom learning**
- **Present proposal to student curriculum subcommittee**
- **Present proposal to faculty curriculum subcommittee**
- **Present proposal (or faculty present proposal) to Executive Curriculum Committee**
- **Once approved, meet with faculty leadership to plan implementation**

pored through our pre-clinical curriculum to identify critical dependencies between climate change and human health. Through this organic, real-time process, we gleaned relevant topics of pathophysiology to contextualize and reinforce with the most fundamental concepts within climate and health literature. We theorized that examples of climate and health linkages in every module, however brief, would both justify our request to include this content and give students the foundation to engage the growing evidence-base on the impacts of climate change on human health toward life-long learning. We sought feedback from our mentor and engaged key administrators and faculty to refine our curriculum. We knew real-time, first-hand opportunities for incorporating climate content, while school leadership understood the resources and approaches to make our curriculum feasible.

A Disseminated Model Replicable in All Medical Schools

Our process resulted in a disseminated curricular plan of climate and health content with proposed learning objectives dispersed across numerous subjects within the pre-clinical years (Table 1). The objectives of our curriculum are 2-fold: to educate students on the links between climate change and health as they relate to pathophysiology in the pre-clinical years of medical school, with particular emphasis on the disproportionate burden on under-resourced communities; and to prepare students to address the root causes of the problem by focusing on structural inequities and the healthcare system’s carbon footprint. The content throughout the pre-clinical years provides a scaffold for medical students to understand how local and global climate trends—combined with the built and natural environment—affect health

Table 1. Climate and health learning objectives for preclinical medical education: linked to existing content.

MODULE	TEACHING FORMAT
Introduction to the Health Sciences	
<i>Climate and Environmental Health Introduction</i>	
<ul style="list-style-type: none"> Define the Anthropocene, planetary health, and climate change. 	Lecture
<ul style="list-style-type: none"> Explain the unequal burden of climate change on the poor, the young, the elderly, communities of color, and those who have contributed least to carbon pollution. 	
<ul style="list-style-type: none"> Outline a climate change-environmental exposure pathway through which climate change affects human health or disrupts healthcare delivery. 	
<i>Discussion of the Climate Crisis and Human Health</i>	
<ul style="list-style-type: none"> Delineate the relative contribution of aspects of healthcare delivery to healthcare's carbon footprint. 	Small Group
<ul style="list-style-type: none"> Discuss how medical professionals advocate climate solutions among patients and colleagues. 	
Community Health & Social Determinants of Health	
<i>Case-Based Learning: Urban Health and the Built Environment</i>	
<ul style="list-style-type: none"> Define urban heat islands, the built environment, and urbanization. 	Case-Based Learning
<ul style="list-style-type: none"> Articulate how the physical environment mediates behavior with implications for physical and mental health. 	
<ul style="list-style-type: none"> Describe how racially discriminatory policies, including historical redlining, manifest in structural inequalities, the built environment, and risk of harm from environmental exposures (eg, heat). 	
<i>Environmental Justice</i>	
<ul style="list-style-type: none"> Define environmental justice and environmental racism. 	Small Group
<ul style="list-style-type: none"> Discuss the Flint Water Crisis and Dr. Mona Hanna-Attisha's role in advocating change. 	
<ul style="list-style-type: none"> Explore opportunities for medical providers and trainees to advance environmental justice. 	
Gerontology	
<i>Geriatric Preventive Health</i>	
<ul style="list-style-type: none"> Apply the physiology of temperature regulation to extreme heat scenarios. 	Lecture
<ul style="list-style-type: none"> Explain the vulnerability of older adults to dehydration, heat exhaustion, and heat stroke. 	
<ul style="list-style-type: none"> Differentiate between the epidemiology and pathophysiology of classic and exertional heat stroke. 	
Microbiology and Infectious Disease	
<i>Introduction to Microbiology</i>	
<ul style="list-style-type: none"> Define "vector-borne disease" and "zoonotic disease." 	Lecture
<ul style="list-style-type: none"> Articulate environmental factors that affect the spread of infectious diseases using a planetary health framework. 	
<i>Case-Based Learning: Epidemiological Consequences of Climate Change</i>	
<ul style="list-style-type: none"> Analyze changes over time in the seasonal and spatial epidemiology of a vector-borne or zoonotic disease and suggest implications for physicians' differential diagnoses. 	Case-Based Learning
<ul style="list-style-type: none"> Evaluate how climate change contributes to seasonal and spatial changes in disease epidemiology directly and indirectly via host, pathogen, and environmental factors. 	
Dermatology	
<i>Atopic Dermatitis</i>	
<ul style="list-style-type: none"> Describe the positive correlation between levels of ozone and particulate air pollution and exacerbations of atopic dermatitis. 	Lecture
<i>Skin Cancer</i>	

(Continued)

Table 1. (Continued)

MODULE	TEACHING FORMAT
<ul style="list-style-type: none"> Link human-driven atmospheric ozone depletion and levels of (UV) radiation exposure. 	Lecture
<ul style="list-style-type: none"> Connect the risk of UV exposure, climate change, and skin cancer. 	
Pulmonology	
<i>Asthma</i>	
<ul style="list-style-type: none"> List sources of particulate matter pollution and differentiate between coarse (PM10) and fine (PM2.5) particulate matter. 	Lecture
<ul style="list-style-type: none"> Illustrate how particulate matter air pollution affects respiratory health in children and adults. 	
<i>Case-Based Learning: Lung Disease</i>	
<ul style="list-style-type: none"> Describe how environmental pollution compromises pulmonary function and lung development. 	Case-Based Learning
<ul style="list-style-type: none"> Analyze socioeconomic and racial disparities in lung health related to zoning, transportation, and other policies that result in disproportionate air pollution levels in communities of color. 	
Cardiology	
<i>Congenital Heart Disease</i>	
<ul style="list-style-type: none"> Outline the risk of maternal ambient heat exposure for fetal development and congenital heart disease. 	Lecture
<i>Atherosclerosis</i>	
<ul style="list-style-type: none"> Describe how air pollution exposure contributes to vascular remodeling and atherosclerosis through oxidative stress and inflammation. 	Lecture
<ul style="list-style-type: none"> Interpret how environmental stressors affect cardiovascular mortality and disease burden. 	
<i>End-Stage Congenital Heart Failure and Cardiac Transplant</i>	
<ul style="list-style-type: none"> Examine how natural disasters disrupt healthcare delivery. 	Lecture
<ul style="list-style-type: none"> Propose methods to support patients reliant on medical devices (eg, left ventricular assist device (LVAD) and hemodialysis) in extreme weather scenarios. 	
Gastrointestinal	
<i>Enteric Infections & Diarrheal Disease</i>	
<ul style="list-style-type: none"> Explain the relevance of Water, Sanitation and Hygiene (WASH) infrastructure to enteric disease transmission. 	Lecture
<ul style="list-style-type: none"> Describe how precipitation changes and flooding influence the burden of diarrheal disease. 	
Renal & Genitourinary Systems	
<i>Pathology of the Upper Urinary Tract</i>	
<ul style="list-style-type: none"> Link warming climate to increased incidence of urolithiasis. 	Lecture
<ul style="list-style-type: none"> Discuss how urolithiasis incidence impacts healthcare system costs. 	
<i>Case-Based Learning: Renal Physiology</i>	
<ul style="list-style-type: none"> Describe how the kidneys respond to heat stress to maintain temperature and water homeostasis and the implications of heat stress for renal function. 	Case-Based Learning
<ul style="list-style-type: none"> Define chronic kidney disease of unknown origin and the hypothesis of heat stress nephropathy. 	
Endocrine	
<i>Introduction to the Global Syndemic</i>	
<ul style="list-style-type: none"> Define the "Global Syndemic" of obesity, malnutrition, and climate change. 	Lecture
<ul style="list-style-type: none"> Evaluate how food insecurity drives paradoxical epidemics of malnutrition and obesity. 	

(Continued)

Table 1. (Continued)

MODULE	TEACHING FORMAT
<i>Food in a Changing Climate</i>	
<ul style="list-style-type: none"> Summarize the effect of climate change on food supplies via extreme weather and decreased micronutrient levels. 	Small Group
<ul style="list-style-type: none"> Articulate how some agricultural practices contribute to climate change, worsen food insecurity, and exacerbate noncommunicable disease. 	
<ul style="list-style-type: none"> Integrate counseling on sustainable diets, emphasizing health and environmental benefits, into patient well-care scenarios. 	
Reproductive Health	
<i>Maternal and Fetal Health</i>	
<ul style="list-style-type: none"> Explain how climate change exacerbates gender inequities and disproportionately harms women and girls. 	Lecture
<ul style="list-style-type: none"> Relate climate-associated environmental effects such as extreme heat, food insecurity, and an expanded range of vector-borne diseases to risks of adverse outcomes for maternal and fetal health. 	
Neurology	
<i>Cerebrovascular Disease</i>	
<ul style="list-style-type: none"> Identify temperature extremes as risk factors for acute cerebrovascular accident. 	Lecture
<ul style="list-style-type: none"> Identify heat exposure and pollution as risk factors for cerebrovascular disease. 	
Psychiatry	
<i>Mental Health and Climate Change</i>	
<ul style="list-style-type: none"> Illustrate the consequences of population displacement, food insecurity, and trauma on mental health. 	Lecture
<ul style="list-style-type: none"> Identify the mental health benefits of climate solutions (eg, bike and walk commuting, green space expansion, and reduced air pollution from clean energy). 	
<ul style="list-style-type: none"> State how antipsychotic medications influence thermoregulation. 	
<ul style="list-style-type: none"> Propose ways for communities to cultivate resilience in the face of climate change. 	

and wellness. The curriculum provides a knowledge base on which to build in the clinical years and beyond.

Lessons Learned: Making the Case for a Disseminated Climate Curriculum

The idea of students and clinicians learning from each other towards teaching sustainability in medicine and further securing transformation to sustainable healthcare has shown promise abroad.¹⁷ In our experience, this approach supports timely integration of training for future doctors about climate change—and climate as a determinate of health—in the United States as well. This collaborative creation of curricular content models the interdisciplinary engagement necessary to address the complexities of climate change in medicine, inspires and empowers trainees to lead within an evolving clinical space that will define our careers, and supports urgent, adaptive, institutional change.

We anticipated that the biggest barrier to our curriculum would not be lack of concern about climate change or undervaluation of its impact on health, social justice, and healthcare delivery, but rather, the logistics of adding anything to an already tight

curriculum at a time when administrators are aiming to reduce overall classroom time. To preempt concerns around time constraints, we quantified the time this curriculum would add to overall classroom learning. An introductory lecture on climate and health and another lecture related to nutrition would add 2 hours of learning, but the bulk of our content could be condensed into a slide or 2 for a given topic. We calculated the projected amount of time our curriculum would include as a proportion of the total hours of pre-clinical teaching. Our proposal would amount to less than 0.2% of total curricular time.

Members of both the faculty and student curriculum committees initially suggested an elective for second or fourth-year students as an alternative to our disseminated proposal. Their approach would mirror the output of several medical schools offering climate and health electives to students.¹⁸ However, there are inherent deficits of an elective model. An elective is by definition self-selecting and exclusive: students with significant knowledge deficits in the subject area may miss the opportunity to gain critical education. An elective would also signal to students that the implications of climate

change on health are non-essential content rather than critical knowledge for every physician—a message that undermines the educational mobilization required at this moment. A disseminated program guarantees all students exposure to climate and health education, while laying a foundation for future learning, and ultimately was endorsed by our Executive Curriculum Committee.

Implementation Opportunities and Challenges

Once our curriculum was approved, we were surprised to receive encouragement from faculty to transpose content from lectures to small group learning—a space we presumed least flexible for curricular additions. Faculty preferred small groups for their ability to foster dialogue, critical thinking and active learning in comparison with lectures. We hope these may further undergird our aim for co-production of knowledge. In a small group on environmental racism, for example, students may ask questions probing the health impacts of the built environment or the disproportionate toll of air pollution on communities of color. Case-based learning also offers flexibility for study of climate change and environmental exposure pathways that affect health. In a session during the renal module, students may learn aspects of heat stress nephropathy: knowledge toward creation of a plan of care with an at-risk patient on rehydration and limiting heat exposure. We hope that by providing space for these conversations, the curriculum will inspire more students and faculty to collaborate and pursue climate solutions.

Many challenges remain. The abrupt transition to virtual learning during the COVID-19 pandemic has presented unexpected hurdles for lecturers adapting their teaching modalities and concerned about student screen fatigue and students unaccustomed to learning from home. Despite these obstacles, in the first weeks of medical school, all first years participated in a virtual, interactive lecture, “Introduction to Climate Change and the Practice of Medicine.” We continue to employ a co-production of knowledge framework as we work with faculty to hone and incorporate content in a step-wise fashion, starting with early modules where strong links exist between existing content and our learning objectives. We know that the curriculum will evolve and that its long-term success depends on buy-in from the many faculty members involved in teaching medical students. The curriculum also requires engagement by some medical students wary of embracing a topic beyond the scope of United States Medical Licensing Examinations (USMLE)—at least unless and until USMLE includes climate change content. However, our experience demonstrates how students can partner with their institutions to win support for educating future doctors on climate and health in keeping with the policy statement of AMA and others.

COVID-19 has underscored the challenges of healthcare delivery and medical education in a time of global pandemic. Economic and public health recovery amidst the climate crisis

demands urgent, collective mobilization toward decarbonizing industries—including healthcare—and rebuilding our economy as environmentally sustainable and supportive of human health. To prepare for future challenges in medicine and healthcare delivery, we cannot delay teaching medical students about climate change and health. This disseminated climate curriculum will benefit students and, above all, the patients and communities we serve.

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Authors' Contributions

Authors BMR and EBL led this curriculum design effort. RPP provided technical expertise throughout the curriculum design process. All authors contributed to the drafting, editing, and reviewing of this paper. No financial disclosures were reported by the authors of this paper.

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