Climate Change and the Practice of Medicine: Essentials for Resident Education
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Abstract

Despite calls for including content on climate change and its effect on health in curricula across the spectrum of medical education, no widely used resource exists to guide residency training programs in this effort. This lack of resources poses challenges for training program leaders seeking to incorporate evidence-based climate and health content into their curricula. Climate change increases risks of heat-related illness, infections, asthma, mental health disorders, poor perinatal outcomes, adverse experiences from trauma and displacement, and other harms. More numerous and increasingly dangerous natural disasters caused by climate change impair delivery of care by disrupting supply chains and compromising power supplies. Graduating trainees face a knowledge gap in understanding, managing, and mitigating these many-faceted consequences of climate change, which—expected to intensify in coming decades—will influence both the health of their patients and the health care they deliver. In this article, the authors propose a framework of climate change and health educational content for residents, including how climate change (1) harms health, (2) necessitates adaptation in clinical practice, and (3) undermines health care delivery.

The authors propose not only learning objectives linked to the Accreditation Council for Graduate Medical Education core competencies for resident education but also learning formats and assessment strategies in each content area. They also present opportunities for implementation of climate and health education in residency training programs. Including this content in residency education will better prepare doctors to deliver anticipatory guidance to at-risk patients, manage those experiencing climate-related health effects, and reduce care disruptions during climate-driven extreme weather events.

To care for patients in the changing climate, tomorrow’s physicians require education on the health effects of climate change today. Climate change poses unprecedented risks to health and welfare, particularly those of children, the elderly, pregnant women, those with existing chronic health conditions, and those living in poverty.1–2 The burning of fossil fuels and other industrial and agricultural activities have increased heat-trapping greenhouse gases in Earth’s atmosphere. As a result, sea levels are rising, oceans are more acidic, and extreme weather events, including hurricanes, droughts, floods, forest fires, and heat waves, are more dangerous. These effects of climate change alter the incidence and severity of illnesses and impair the ability of physicians and health care systems to deliver medical care.

The Case for Climate Change and Health Education for Residents

Because of the far-reaching implications of climate change for health, authors have recently called upon physicians to learn more about it.1 The American Medical Association (AMA) passed a resolution in June 2019 supporting inclusion of climate change and health in medical education at the undergraduate, graduate, and continuing medical education levels.4 More than 70 health care organizations, including the AMA, the American College of Physicians, the American College of Emergency Physicians, the American Academy of Pediatrics, and Physicians for Social Responsibility, have declared climate change a health emergency and advocated greater engagement of the health sector in climate action.5

Residents in all specialties require basic knowledge of the health effects of climate change to care for patients amid the ongoing climate crisis; however, the specific application of this knowledge to patient care and health care delivery varies by specialty. Residents in emergency medicine benefit from relatively more training in disaster response. Those in internal medicine, family medicine, and pediatrics must learn to tailor anticipatory guidance to protect patients from climate-related health threats. Any resident involved in direct patient care will confront climate-related mental health concerns—from anxiety about what climate change portends to a greater incidence of mental health symptoms and disorders stemming from disruption of life and livelihoods, displacement, disasters, and heat exposure—which, in turn, necessitate close coordination with psychiatry and mental health services.

Residents are poised to learn routine guidance to provide to patients on healthier habits that reduce greenhouse gas emissions, and the right training can empower residents to advocate (in their places of practice, within medical societies, and through policy change) climate measures that reduce harms to human health and promote health equity.6 To that end, in this article, we propose the first (to our knowledge) climate and health curricular framework for medical residents linked to the Accreditation Council for Graduate Medical Education (ACGME) core competencies.
A Framework for Climate and Health Content

Here, we provide evidence-informed content on climate change and health organized into 3 domains: (1) knowledge of climate change and its effects on health, (2) climate change–related adaptations for clinical practice, and (3) implications of climate change for health care delivery. Appendix 1 distills the evidence base into specific learning objectives (LOs) for trainees at the graduate medical education level. While crafted for generalist programs—pediatrics, internal medicine, and family medicine—whose leaders seek to address expeditiously the climate and health knowledge gap of graduating residents, this framework could be adapted to meet program needs across specialties.

Knowledge of climate change and its effects on health

Heat-related illness. Since heat waves are becoming more frequent and severe throughout the United States, physicians must understand that extreme heat poses a direct threat of heat exhaustion, heat stroke, and increased mortality.7 Heat waves worsen common illnesses, including asthma, mental health disorders, diabetes, renal insufficiency, and infectious gastrointestinal diseases.2 Maternal exposure to extreme heat during pregnancy is linked to premature birth, low birth weight, and congenital anomalies.4 Risk for heat-related illness varies with location, age, activities, and socioeconomic and health status. Some populations (e.g., infants, the elderly, pregnant women) are more vulnerable to extreme heat, while others (e.g., athletes, outdoor workers, those without air-conditioning) are at greater risk of exposure. Research suggests that physiologic and behavioral adaptations occur over time: those least accustomed to heat face greater risk of heat-related illness.9 Training on the health implications of extreme heat in populations with physiologic vulnerability or greater risk of exposure will better prepare physicians to recognize heat illness and provide targeted counseling—like heat action plans—to at-risk patients.

Air quality and respiratory illness.

Climate change complicates air quality and respiratory health in several ways.10 While aeroallergens and pollution are important triggers for asthma, providers and patients may not routinely monitor air quality and pollen indices to proactively inform disease management. Both the prevalence and severity of environmental allergies are increasing because of climate-driven factors: longer pollen seasons, more pollen, and increased pollen potency.11,12 Climate change also contributes to air pollution, which impairs lung development in children and contributes to asthma burden in patients of all ages.1,13 Higher temperatures promote the formation of ground-level ozone. Inhaled ozone decreases lung function and increases asthma incidence and severity, with those of low socioeconomic status disproportionately harmed.10 The joint effects of heat and ozone exposure may result in hundreds of thousands of school absences and over 1 million cases of acute respiratory symptoms by 2030 if greenhouse gas emissions continue on the same trajectory.14

Particulate air pollution also causes oxidative stress and inflammation, which contribute to asthma exacerbations and decreased lung function—even in individuals without asthma.13,15 In addition to air pollution from industry and transportation, wildfires linked to drought and heat create particulate pollution that degrades air quality over large areas.16 In 2018, the San Francisco Bay Area had the worst air quality in the world because of wildfire smoke,17 and particulate matter from these fires reached all the way to Massachusetts.18 Further, climate models suggest that wildfires and associated particulate pollution are likely to increase in the arid west and in eastern Canada, affecting multiple U.S. East Coast cities.1 Wildfire smoke contains a host of pollutants, including acrolein (a lung irritant), benzene (a carcinogen), and polyaromatic hydrocarbons (carcinogens and neurotoxins). Particulate respirators that are certified N95 or P100 help protect adults exposed to outdoor smoke or those who experience health effects from outdoor or indoor smoke.18 Because tight mask seals are not possible for children, families with young children are advised to minimize exposure and use household high-efficiency particulate air filters when possible. Physicians need to understand air quality recommendations relevant to their patients and provide appropriate guidance based upon them.

Infectious diseases. Climate change is altering where and when vector-borne diseases occur. Lyme disease is the most prevalent vector-borne disease in the United States.20 Lengthier warm seasons, milder cold seasons, and land use changes have enabled *Ixodes scapularis* ticks that carry the Lyme disease bacterium (i.e., *Borrelia burgdorferi*) to extend their range northward each season. Lyme disease is expected to become even more widespread in the continental United States, and infections will likely occur earlier in the spring and linger later into the fall due to a lengthened tick season.21 Climate change also influences the range of *Aedes* species mosquitoes and may create conditions more favorable for spread of dengue, chikungunya, and Zika in some parts of the United States.22

Climate change has intensified Earth’s water cycle; heavy downpours are more common in the United States and are projected to worsen in coming decades.23 Heavy rainfall increases pathogen load in municipal drinking water systems and contributes to outbreaks of waterborne diseases, particularly in children.24 Transmission of pathogens via piped water in the United States has been estimated to result in millions of cases of acute gastroenteritis each year.25 Climate-sensitive waterborne pathogens include the following: *Campylobacter, Cryptosporidium, Escherichia coli, Giardia, hepatitis A virus, nontyphoidal Salmonella*, and *Shigella*.26 To avoid delays in diagnosis and provide appropriate care, physicians must adapt their differential diagnoses of infectious etiologies based upon the changing climate.

Malnutrition and food insecurity. In 2017, 2.9 million households in the United States, including 15.7% of those with children, were food insecure.27 Climate change can destabilize food systems and promote food insecurity.28 Extreme weather events damage crops, harm livestock, and disrupt food distribution. Some food crops contain lower levels of iron, zinc, and protein when grown under higher carbon dioxide concentrations, potentially increasing risk of micronutrient deficiencies as carbon dioxide concentrations accumulate.29 Climate models predict more droughts in the nation’s produce- and meat-producing regions.27 Agricultural losses from extreme weather events may drive higher food prices, further contributing
to food insecurity. While some physicians already routinely screen for this social determinant of health, physicians have ever more reason to screen for food insecurity and take proactive measures (e.g., providing referrals to food banks) to prevent hunger when acute shocks to the food system, such as the COVID-19 pandemic, arise.

**Injuries and toxic exposures.** Climate-driven extreme weather poses risks of direct injury as well as indirect illness from toxic exposures. Hurricanes and extreme flooding have mobilized coal ash and chemicals from storage sites, with risks for surrounding communities. In 2018, Hurricane Florence caused the breaches of coal ash pits into the Neuse and Cape Fear Rivers and into recreation areas in North Carolina. Many other storage sites are vulnerable to similar breaches and subsequent flooding. Children living near coal ash, which contains heavy metals, including lead, arsenic, and mercury, have a greater incidence of allergies, gastrointestinal complaints, and attention-deficit/hyperactivity disorder requiring recognition and referrals. Hurricane Harvey deposited more than 5 feet of rain over parts of Houston, Texas, in 2017, inundating 5 Environmental Protection Agency–designated Superfund sites, which are laden with toxic substances, and flushing more than 500,000 gallons of gasoline from storage tanks.

Extreme weather events are the most common cause of power failures in the United States, affecting about 25 million people per year. After storms that cause power outages, carbon monoxide poisonings increase due to reliance on poorly ventilated or poorly functioning generators. In the 9 days following landfall of Hurricane Irma in 2017, there were 91 carbon monoxide poisonings in Miami-Dade County alone. In all states impacted by Hurricane Irma, there were more deaths from carbon monoxide poisoning than from direct injury from the hurricane itself.

Climate change is also contributing to the emerging risk of exposure to harmful algal and cyanobacterial blooms. Warmer temperatures and heavy rainfall (which flushes nitrogen and phosphorus into coastal waters and lakes) promote the growth of algae and cyanobacteria. With sufficient nutrients, sunlight, and slow-moving water, blooms produce toxins that cause rashes (with contact), vomiting and diarrhea (if ingested), and breathing difficulty (when aerosolized and inhaled). As blooms are becoming more common, the One Health Harmful Algal Bloom System—a national system tracking algal blooms and their influence on health—was launched in 2016 to quantify the effects of this emerging threat. As illnesses associated with harmful algal and cyanobacterial blooms become more common and better characterized, physicians need to understand their presentation and management.

**Mental health disorders and displacement.** Climate change increases the odds that an individual will experience protracted disruption of routines and psychological trauma. Exposure to extreme weather is associated with adverse mental health outcomes in children and adults, including posttraumatic stress disorder, anxiety, and depression. Among children exposed to extreme weather events, more than a third receive new mental health diagnoses and more than 10% have persistence of symptoms a year after the event. One of the most powerful determinants of mental health concerns is displacement. Almost 2 years after Hurricane Katrina, approximately 85% of 372,000 displaced children had not returned home. Their parents reported persistent emotional or behavioral challenges, gaps in schooling, and challenges to accessing pediatric health care. Disasters also stress caregivers and undermine support systems for parents. By compounding parental stress and mental health concerns, displacement contributes to adverse childhood experiences, which can harm the emotional and social development of children, affecting them into adulthood. About 24 million people worldwide have been displaced each year since 2008 due to extreme weather and other climate-related disasters. Familiarity with behavioral and mental health sequelae of displacement is a prerequisite for physicians to screen for them, which, in turn, supports trauma-informed care for locally and globally displaced climate migrants.

Extreme weather events intensify the risk factors, including chronic stress, economic insecurity, food insecurity, and social isolation, that contribute to poorer mental health. As one example, according to multiple studies, exposure to heat has been associated with suicide risk in adults. Climate change has led to many reports of anxieties about the effects of its harms on human existence and a fear of environmental doom—so-called ecoanxiety. At the same time, emerging evidence indicates that climate change mitigation can improve mental health outcomes. Greater exposure to greenspace throughout childhood, for instance, has been associated with a markedly lower risk of mental health disorders. By recognizing climate change–related determinants of mental health, trainees will more ably care for at-risk patients, provide referrals for mental health services, and coordinate care with psychiatry colleagues.

**Climate change–related adaptations for clinical practice**

Knowledge of the pathways that link climate change and health will enable residents to integrate patient- and location-specific climate risks into more effective disease prevention and treatment plans. Tailored guidance will help patients and families avoid harmful climate-related exposures and prepare for the sequellea, especially those related to health, of climate change. The young, the elderly, those with chronic diseases (e.g., diabetes, asthma), those with physical or developmental disabilities, and those dependent on mechanical therapies (e.g., dialysis, ventilator support) all require additional counseling (Chart 1). Potential barriers to accessing care due to climate-driven disasters make contingency planning essential, especially for vulnerable individuals. Patients face changing risks because of climate change; future physicians require training to adapt care plans to these changing risks.

Physicians have an obligation to inform patients about treatments that pose heightened risks because of climate change. Many common medications (e.g., beta-blockers, stimulants, diuretics, laxatives) affect body temperature or water homeostasis and confer added risk of heat illness and dehydration in heat waves. Antihistamines (e.g., diphenhydramine), anticholinergics, carbonic anhydrase inhibitors (e.g., acetazolamide), and tricyclic antidepressants (e.g., amitriptyline) can affect thermoregulation and impair sweating. Other medications necessary
### Chart 1

**At-Risk Patient Populations and Their Vulnerabilities in Climate-Related Extreme Weather**

<table>
<thead>
<tr>
<th>Patient population</th>
<th>Climate-related vulnerability</th>
<th>Implications for the education of trainees</th>
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<tbody>
<tr>
<td>Patients with chronic conditions, including those who …</td>
<td>Chronic illnesses increase the risk of poor outcomes due to disruptions in care and/or increased dependence on caregivers</td>
<td>Education should include training in preparedness, particularly the development of emergency care plans for patients to use during climate-based or other disruptions to usual access to medications, services, electricity, and equipment. Education should prepare future physicians to advocate for these at-risk patients beyond the exam room and to encourage intentional consideration of individual, family, and community needs, as well as health systems resilience, in disaster preparedness and response plans.</td>
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<td>Patients who are postsurgical, hospitalized, or acutely ill</td>
<td>Acute illnesses require health services or follow-up care; thus, those with such illnesses have an increased risk of poor outcomes due to inaccessible care or disruptions in care</td>
<td>Trainees should be educated on alternative follow-up care options that can be used in climate-driven natural disasters and during health systems disruptions or other emergencies (e.g., telehealth, phone calls to check on patients, home health nurses).</td>
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<tr>
<td>People who are elderly</td>
<td>Old age increases physiologic and social vulnerabilities to environmental exposures; older patients are more likely to be dependent on caregivers for the activities of daily living, to have reduced mobility, and to be socially isolated</td>
<td>Trainees caring for the elderly should be instructed in assisting the patient (and family) in proactively identifying and activating backup plans, if needed, to check on the patient; ensure access to basic needs, and ensure continuation-of-care plans. Trainees should be taught and observed in giving anticipatory guidance to the elderly and their families regarding climate-related risks and mitigation of these risks.</td>
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<tr>
<td>Neonates and infants</td>
<td>The very young are physiologically vulnerable to environmental exposures; at risk for disruptions to optimal development; dependent on the health and well-being of their caregiver(s) for their own; and require special consideration for all aspects of wellness, including feeding, stooping, and sleeping</td>
<td>Education of trainees should include learning how to give anticipatory guidance to parents of young children regarding climate and environmental exposures, preparing for emergencies and disruptions, and reducing children's risks and exposures.</td>
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<td>Pregnant women</td>
<td>Pregnancy increases physiologic and social vulnerability to environmental exposures; the health of both the mother and the fetus are at risk</td>
<td>Residency training should include education on climate risks and environmental exposures that jeopardize the health of the mother and/or fetus.</td>
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<tr>
<td>Athletes, the military, and outdoor workers</td>
<td>Outdoor activities increase the likelihood of exposure and, in turn, the risk of heat-related illness</td>
<td>Residents require training on the contribution of exercise, personal protective equipment, and exposure variables to climate-related disease, as well as strategies for helping patients avoid or minimize the risk of exposure. Programs can educate residents on the role of physicians in advocating (and provide residents the opportunity to engage with) policy frameworks and society guidelines that protect these groups.</td>
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<tr>
<td>People who are experiencing homelessness or who do not have stable housing</td>
<td>People who do not have reliable shelter are socially vulnerable and have no guaranteed protection from the elements</td>
<td>Homeless, poor, displaced, and linguistically isolated persons and families are all extremely vulnerable. Trainee education should include experiences with vulnerable patients to better understand their environmental determinants of health (including structural racism manifest in the environment), the specific challenges they face, and the community support systems and resources available to these groups. While learning how to provide anticipatory guidance for patients is important (e.g., in a heat wave seek out shade, drink more water, access a shelter), residency education should also include training in how to advocate shelter, food, mental health resources, medical care, medication, and support for these individuals.</td>
</tr>
<tr>
<td>Low-income families</td>
<td>Historically neglected low-income communities, particularly low-income communities of color, face disproportionate exposure from a legacy of structurally racist polices and/or may have fewer resources to adapt to and avoid environmental exposures to safeguard health</td>
<td>Residency training should include education on climate-related disease and its implications for the education of trainees. Trainees require training on the contribution of exercise, personal protective equipment, and exposure variables to climate-related disease, as well as strategies for helping patients avoid or minimize the risk of exposure. Programs can educate residents on the role of physicians in advocating (and provide residents the opportunity to engage with) policy frameworks and society guidelines that protect these groups.</td>
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<tr>
<td>Evacuees or others experiencing displacement</td>
<td>Displaced persons are socially vulnerable and face challenges, such as family separation, lack of access to care, increased risk of exploitation, and mental health concerns, including increased risk of adverse childhood experiences</td>
<td>Residents require training on the contribution of exercise, personal protective equipment, and exposure variables to climate-related disease, as well as strategies for helping patients avoid or minimize the risk of exposure. Programs can educate residents on the role of physicians in advocating (and provide residents the opportunity to engage with) policy frameworks and society guidelines that protect these groups.</td>
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<tr>
<td>Linguistically isolated individuals and families (those who do not speak the language/s of the general population)</td>
<td>Linguistically isolated families are less likely to have access to community resources, including emergency public service announcements</td>
<td>Residents require training on the contribution of exercise, personal protective equipment, and exposure variables to climate-related disease, as well as strategies for helping patients avoid or minimize the risk of exposure. Programs can educate residents on the role of physicians in advocating (and provide residents the opportunity to engage with) policy frameworks and society guidelines that protect these groups.</td>
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for acute illness management have altered pharmacology (e.g., epinephrine, insulin) or altered dose delivery (e.g., albuterol) above room temperature. Medications stored outdoors or in cars or delivered by mail order can be exposed to temperatures above those recommended for ensuring medicine integrity and proper medical device function.

Physicians also can provide guidance in routine clinical encounters on lifestyle choices that not only improve individual health in the near term but also collectively reduce greenhouse gas emissions and help secure public health gains in the long term. Reduced reliance on single-occupancy vehicles and the use of alternative transportation options improve local air quality, reduce risks of harm from pollution, and improve physical fitness. The EAT-Lancet Commission on healthy diets from sustainable food systems emphasizes the importance of a plant-rich diet. Less consumption of red meat reduces greenhouse gas emissions while lowering the personal risk of chronic diseases, including colon cancer and premature death.

Implications of climate change for health care delivery
Health care delivery and disaster preparedness. Climate change promotes disasters that both disrupt health care operations and require new strategies to safeguard care delivery. Supply shortages, power failures, and surges in patient volume necessitate robust disaster preparedness plans that include trainees. Even with plans in place, managing vulnerable patients in disasters is difficult. For example, patients at New York University’s Langone Medical Center required evacuation during Hurricane Sandy when power systems failed. Without electricity or access to electronic health records (EHRs), physicians—including residents—were integral to coordinating safe evacuation.

Resident trainees care for patients around the clock in many medical centers, yet they often have the least training in what to do in a disaster or power failure. Although many facilities have backup power, the duration of a blackout may exceed the time generators can power facilities—including servers that store EHR data. Most trainees have never used paper charts or functioned without EHRs and would benefit from training on how to write paper orders and how to navigate paper charts. Physicians and health facilities around the United States need to coordinate with public health officials and with one another during disasters when information, electrical, pharmacy, and/or laboratory systems may be compromised. Residents will be better equipped to minimize disruptions in patient care during disasters if they are included in disaster drills and integrated into a facility’s preparedness plan.

Extreme weather events threaten the availability of supplies and medications by not only disrupting the cold chain (i.e., the transport of items such as vaccines that require specific temperatures) and supply chains but also damaging production facilities. Hurricane Maria (September 2017) disabled a factory in Puerto Rico that produces small-volume intravenous fluid bags. As a result, hospitals struggled to provide essential fluids and medications well into 2018. After Hurricane Maria, the U.S. Food and Drug Administration monitored a list of 90 medical products for shortages, including 40 drugs. Disasters also create mismatches between patient need and health system demand, creating surges in volume from neighboring areas and even international sites. In 2017, Hurricane Irma prompted the evacuation of almost 7 million people from Florida, and physicians in regional centers such as Atlanta, Georgia, cared for climate migrants displaced from their familiar physicians and medical centers. In individuals displaced by global climate-related disasters and conflict, U.S. physicians may see unusual infectious diseases or more severe presentations of common illnesses.

Reducing health care’s contribution to pollution-related morbidity and mortality. Health care is the second most energy-intensive sector in the United States, producing 9%–10% of U.S. greenhouse gas emissions. The amount of pollution associated with the U.S. health care system is responsible for an estimated loss of about 405,000 disability-adjusted life years—on par with the lives lost due to medical error. Many hospitals and academic health centers face mandates from their states or municipalities to achieve net-neutral greenhouse gas emissions. Efforts to improve health care efficiency, reduce waste, and reign in unnecessary resource expenditure on deviations from evidence-based guidelines that result in overdiagnosis and overtreatment will all aid institutions in these efforts. To comply with the ACGME’s mandate that trainees participate in quality improvement (QI) projects through their residency program, faculty and residents could create QI projects to advance institutional decarbonization, disaster preparedness, or climate resiliency. Program directors, hospital leaders, and institutional officials can incorporate lessons learned from previous climate events to prepare their institutions and trainees for climate-associated disasters.

Physicians as climate advocates
The climate-and-health education outlined above will empower future physicians as advocates who can represent the health implications of climate change to policymakers and legislators. By presenting the health, including mental health, basis for climate change mitigation and adaptation measures, physicians can help encourage policies that safeguard the health of patients. For example, more exertional heat illness occurs in states that do not have mandated guidelines to reduce heat exposure in high school athletes. Climate change worsens existing health inequities. For example, urban heat islands disproportionately affect communities of color. Disproportionate exposure to extreme heat in these urban settings has been linked to the historical and structurally racist housing policy known as redlining. Physicians can advocate policies that dismantle structural injustice, protect patients, and avoid worsening health inequities among at-risk populations. Chart 1 identifies educational implications to consider in designing curricula to address the large burden of climate-associated conditions that occur in at-risk, vulnerable, disadvantaged, medically complex, or special populations. These principles can be used to build foundational and specialized educational formats and experiences for residency training.
Implementation of Climate and Health Educational Content in Residency Training

Education on climate change and health will benefit physicians caring for patients today and over the coming decades. Given institutional resource constraints and potential lack of faculty expertise, a climate and health toolkit might be coordinated through a national organization that could convene subject matter experts and leaders in residency education. Similar approaches have been taken for the creation of other national curricula. However, this approach will take time, and trainees need to be prepared to care for their patients already experiencing the health impacts of climate change. We recommend, therefore, that training programs use the curricular framework (Appendix 1) for creation of local content while a consortium is creating a more robust national toolkit. The desired outcomes of a climate and health curriculum include demonstrated competencies in the following domains: (1) knowledge of climate change and its effects on health, (2) climate change–related adaptations for clinical practice, and (3) implications of climate change for health care delivery. Built for these outcomes, Appendix 1 includes proposed LOs mapped to ACGME core competencies as well as suitable learning formats and assessment strategies for each LO. Notes and comments about individual LOs are also included. We have provided Appendix 1 especially for program directors without access to individuals with expertise on climate change and health so that they can easily identify the major learning points and clinical conditions that address the LOs of our proposed curriculum. Subspecialty faculty, school of public health faculty (if available), and public health physicians are all individuals who could potentially help integrate and teach portions of this curriculum.

Residency program leaders may design curricula differently so that they are tailored to climate risks for their geography, their local populations, and their missions. Similarly, different programs will use different strategies for implementing LOs and assessing learning. Some residency training programs may choose to integrate LOs into rotations where alignment already exists. For example, education on wildfires and lung disease might be integrated into primary care or pulmonary rotations. Clinical rotations and/or electives in outpatient primary care, social medicine, inpatient care, psychiatry, allergy–immunology, emergency medicine, infectious disease, and nephrology (among others) are also all appropriate places to integrate pieces of the curriculum. Other training programs may prefer to designate a rotation to provide training on most of this content in a concentrated block. LOs could also be delivered at resident noon conferences or academic half days, including via active learning formats, such as small-group, case-based discussions (among others). Because all residents may not see each climate-related condition during the course of their clinical training, the suggested learning formats provide for consistent delivery of material to achieve the LOs for all postgraduate trainees. Notably, some LOs (those further down the list) increase in complexity and cross-competencies. This allows residencies to arrange LOs for knowledge and skill building over the course of delivery of their curriculum.

The Way Forward

In the context of calls from within the United States and around the world for the health sector to prepare for climate change, our proposed curricular framework for residents will support training programs whose leaders are seeking to incorporate climate change and health content. It can inform the development of more detailed content, assessment strategies, and toolkits on this subject. By learning how climate change affects individual and population health, clinical care, and health care delivery, residents will be prepared to care for patients who face growing threats to their health and well-being from climate change.

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Table 1
A Curricular Framework Linking Climate and Health Learning Objectives for Resident Education to ACGME Core Competencies, Suggested Learning Formats, Assessment Strategies, and Specific Curricular Content

<table>
<thead>
<tr>
<th>Learning objectives</th>
<th>ACGME competencya</th>
<th>Core or advanced objectiveb</th>
<th>Learning formatsc</th>
<th>Assessment strategies</th>
<th>Curricular points and notes</th>
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</table>
| Knowledge of climate change and its effects on health                                | MK Core           | • Lecture                   | • MCQs           | • Oral questions      | Extreme heat is associated with increases in the following:  
| Describe the negative effect of extreme heat exposure on health.                    |                   | • Small group               |                  |                      | • Asthma exacerbations,  
|                                                                                     |                   |                             |                  |                      | • Fluid and electrolyte disturbances,  
|                                                                                     |                   |                             |                  |                      | • Heat-related nephropathy,  
|                                                                                     |                   |                             |                  |                      | • Congenital anomalies,  
|                                                                                     |                   |                             |                  |                      | • Infant mortality and poorer pregnancy and perinatal outcomes,  
|                                                                                     |                   |                             |                  |                      | • Skin and soft tissue infections, and  
|                                                                                     |                   |                             |                  |                      | • Suicide. |
| Discuss the links among air pollution (including wildfires), climate change, and their relationship to health. | MK Core           | • Lecture                   | • MCQs           | • Oral questions      | Heat increases ground-level ozone.  
|                                                                                     |                   | • Small group               |                  |                      | Wildfires increase particulate matter air pollution.  
|                                                                                     |                   |                             |                  |                      | Ozone exposure increases the severity of asthma and COPD exacerbations and decreases lung function in children.  
|                                                                                     |                   |                             |                  |                      | Particulate matter pollution worsens asthma and COPD, results in preterm and low-birth-weight infants, and impairs cognitive development. |
| Explain how climate change contributes to more allergic symptoms in patients.       | MK Core           | • Lecture                   | • MCQs           | • Oral questions      | Warm temperatures prolong pollen seasons.  
|                                                                                     |                   | • Small group               |                  |                      | Higher concentrations of atmospheric carbon dioxide result in greater pollen production by allergenic plants (e.g., ragweed). |
| Describe how climate change alters the geographic distribution and incidence of vector-borne diseases and population morbidity. | MK Core           | • Lecture                   | • MCQs           | • Oral questions      | Warming temperatures ...  
|                                                                                     |                   | • Small group               |                  |                      | • Promote the movement of disease-carrying mosquitoes and ticks to new locations and  
|                                                                                     |                   |                             |                  |                      | • May result in the use of more pesticides that can be associated with detrimental effects on neurodevelopment. |
| Discuss the climate events that increase risk of waterborne disease outbreaks and the common pathogens causing disease in these scenarios. | MK Core           | • Lecture                   | • MCQs           | • Oral questions      | Warming and heavy precipitation are associated with increased outbreaks of  
|                                                                                     |                   | • Small group               |                  |                      | Campylobacter, Cryptosporidium, Escherichia coli, Giardia, hepatitis A virus,  
|                                                                                     |                   |                             |                  |                      | nontyphoidal Salmonella, and Shigella. |
| Describe how extreme weather associated with climate change leads to increased risks of malnutrition and food insecurity. | MK Core           | • Lecture                   | • MCQs           | • Oral questions      | Extreme weather events associated with climate change can result in the following:  
|                                                                                     |                   | • Small group               |                  |                      | • Reduced crop yields,  
|                                                                                     |                   |                             |                  |                      | • Harm to livestock,  
|                                                                                     |                   |                             |                  |                      | • Interference with food supply chains (e.g., from fires, floods, storms), and  
|                                                                                     |                   |                             |                  |                      | • Disruption of livelihoods and income. |
| Connect climate-driven natural disasters, such as hurricanes, floods, heat waves, and wildfires, to the associated risks of injury, displacement, and mental health conditions. | MK Core           | • Lecture                   | • MCQs           | • Oral questions      | • Heavy rainfall flushes toxins and heavy metals into the water supply.  
|                                                                                     |                   | • Small group               |                  |                      | • Carbon monoxide poisonings increase with electrical outages due to the use of  
|                                                                                     |                   |                             |                  |                      | • Alternators or alternate heat sources that are poorly ventilated.  
|                                                                                     |                   | • Clinical rotations        |                  |                      | • Natural disasters increase the risk of accidental and nonaccidental trauma, as well as  
|                                                                                     |                   | • Standardized patients    |                  |                      | • mental health disorders.  
|                                                                                     |                   | • Oral questions            |                  |                      | • Displacement from homes and separation of families increase the risk of mental  
|                                                                                     |                   | • Oral presentation (rounds) |                  |                      | health conditions.  

(Appendix continues)
### Appendix 1
(Continued)

<table>
<thead>
<tr>
<th>Learning objectives</th>
<th>ACGME competency</th>
<th>Core or advanced objective</th>
<th>Learning formats</th>
<th>Assessment strategies</th>
<th>Curricular points and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>List the common mental health conditions that occur after climate-associated natural disasters.</td>
<td>MK</td>
<td>Core</td>
<td>• Lecture&lt;br&gt;• Small group&lt;br&gt;• Clinical rotations</td>
<td>• MCQs&lt;br&gt;• Oral questions</td>
<td>Climate-associated natural disasters are associated with increases in the following: • Depression, • Anxiety, • Posttraumatic stress disorder, and • Suicide.</td>
</tr>
</tbody>
</table>

#### Climate change–related adaptations for clinical practice

| MK, PC | Core | • Lecture<br>• Small group<br>• Clinical rotations<br>• Standardized patients | • MCQs<br>• Oral presentations (rounds)<br>• OSCE<br>• Clinical evaluations<br>• Chart audits | Climate change may be related to the following: • Heat exhaustion, • Heat stroke, • Syncope, • Heat-related nephropathy, • Electrolyte imbalances, • Asthma/COPD exacerbations, • Pollution and wildfire smoke exposure, • Seasonal allergies, • Gastroenteritis (viral, bacterial), • Malnutrition, • Micronutrient deficiency, • Poor glycemic control in diabetics, and • Heart failure exacerbations. |

| MK, PC | Core | • Small group<br>• Clinical rotations<br>• Standardized patients | • Oral presentations (rounds)<br>• OSCE<br>• Clinical evaluations<br>• Chart audits | See the list of conditions listed immediately above for climate-related illnesses. • Plans should address managing any acute or chronic problems, identifying and acquiring any resources needed, and providing anticipatory guidance. |

| MK, PC, C | Core | • Small group<br>• Clinical rotations<br>• Role play<br>• Standardized patients | • MCQs<br>• Oral questions<br>• Direct observation<br>• Standardized patient checklist<br>• Clinical evaluations | Extreme heat may alter some of the pharmacologic properties of medications (e.g., insulin, levothyroxine, epinephrine). • Patients need proper storage for their medications. • Some medications increase the risk of heat-related illnesses (e.g., beta-blockers, diuretics, antidepressants, antihistamines). • Aerosolized or pressurized canisters (e.g., albuterol inhalers) may burst at temperatures > 120°F. |

(Appendix continues)
### Appendix 1 (Continued)

<table>
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<tr>
<th>Learning objectives</th>
<th>ACGME competencya</th>
<th>Core or advanced objectiveb</th>
<th>Learning formatsc</th>
<th>Assessment strategies</th>
<th>Curricular points and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify individual-specific risk factors for climate-related illnesses.</td>
<td>MK, PC</td>
<td>Core</td>
<td>• Small group</td>
<td>• Standardized patient checklist</td>
<td>Individual factors that put patients at greater risk for climate-related illnesses include the following: • Young or older age, • Pregnancy, • Sports participation or outdoor occupation, • Exertion, • Chronic medical conditions, • Linguistic isolation, • Structural inequities in the built environment and structural racism, • Lack of family resources (poverty; homelessness; lack of reliable, safe transportation; lack of adequate air-conditioning, heating, and ventilation), • Lack of community resources (lack of shelters, no warning systems for severe weather or air quality), and • Family displacement and/or separation from family members.</td>
</tr>
<tr>
<td>Create patient-tailored heat action plans, asthma/chronic lung disease action plans, disaster preparedness plans, and/or other appropriate guidance with consideration of local climate risks.</td>
<td>PC</td>
<td>Core, advanced</td>
<td>• Clinical rotations</td>
<td>• Oral presentation (rounds)</td>
<td>• Heat plans should include communicating risks; limiting outside activities; dressing properly; increasing intake of fluids; providing advice on keeping home interiors heated, cooled, and ventilated properly; and storing heat-sensitive medications. • Asthma/chronic lung disease action plans should incorporate air quality alerts for sensitive groups, warnings to staying indoors when air quality is poor, and wearing masks when outside, if appropriate for the patient and deemed medically needed. • Disaster preparedness plans should be tailored based on climate risk, health status of family members, food and water supplies, medication supplies, need of a generator (for loss of power), location of shelters, etc.</td>
</tr>
<tr>
<td>Effectively communicate health risks that result from climate change to stakeholders (e.g., patients, family members, community stakeholders, politicians).</td>
<td>MK, C, P</td>
<td>Core, advanced</td>
<td>• Clinical rotations</td>
<td>• Review of drafted plans</td>
<td>• Risks are detailed in this article.</td>
</tr>
<tr>
<td>Advise patients and families on the health benefits of climate mitigation activities, including active transportation and plant-rich diets.</td>
<td>MK, C, P</td>
<td>Core</td>
<td>• Clinical rotations</td>
<td>• Review of oral presentation (rounds)</td>
<td>• Eating more plant-based foods results in a reduction in greenhouse gases (animal agriculture is responsible for significant greenhouse gas production), reduced risk of chronic illnesses, and, potentially, financial savings. • Decreasing food waste decreases carbon footprint. • Active transportation (walking, cycling) reduces automotive emissions and improves fitness.</td>
</tr>
<tr>
<td>Discuss ethical issues related to climate change and its effects on health.</td>
<td>MK, C, P</td>
<td>Core, advanced</td>
<td>• Lecture</td>
<td>• Direct observation of small-group discussion</td>
<td>• The effects of climate change inequitably affect children, the elderly, and marginalized populations. • Future generations have the right to a healthy environment.</td>
</tr>
</tbody>
</table>

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*Appendix continues*
### Appendix 1
(Continued)

<table>
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<tr>
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<th>Assessment strategies</th>
<th>Curricular points and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implications of climate change for health care delivery</strong></td>
<td>PBLI, SBP</td>
<td>Core</td>
<td>• Experiential learning</td>
<td>• Oral presentation (rounds)</td>
<td>Physicians should be aware of the following:</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Clinical rotations</td>
<td>• Chart audits</td>
<td>• Air quality measurements or air quality alerts,</td>
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<td></td>
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<td>• Direct observation</td>
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<td>• Daily pollen counts,</td>
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<td>• Oral presentation (rounds)</td>
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<td>• Locations of toxic substance repositories in the community, and</td>
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<td></td>
<td></td>
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<td>• Local boil water advisories.</td>
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<td>Access state or community resources for environmental health.</td>
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<tr>
<td>Demonstrate effective use of resources such as ProMED, HealthMap, and the CDC website to evaluate nationally relevant vector-borne disease emergence.</td>
<td>PBLI, SBP</td>
<td>Advanced</td>
<td>• Experiential learning</td>
<td>• Direct observation</td>
<td>Adapt place-based differential diagnoses and management plans based on patient history and patterns of disease emergence.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Clinical rotations</td>
<td>• Oral presentation (rounds)</td>
<td>• Discuss the role of physicians in contributing to and responding to early-warning systems in the context of emerging infections and outbreak control.</td>
</tr>
<tr>
<td>Review the hospital’s or practice’s disaster plans and discuss strategies to maintain patient care at a facility compromised by systems failures, such as power outages or electronic medical record disruption.</td>
<td>SBP</td>
<td>Core, advanced</td>
<td>• Small- or large-group review of plans</td>
<td>• Direct observation of evacuation handover with feedback</td>
<td>Know how to access the hospital’s or practice’s disaster preparedness plan and review or practice this plan.</td>
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<td>• Preparatory exercise for disaster training</td>
<td>• Standardized patient checklist</td>
<td>• Demonstrate competence in following medical record downtime procedures and workflows (e.g., writing paper prescriptions).</td>
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<td>• Simulation checklist</td>
<td>• Know, review, and practice roles and responsibilities during different types of disaster scenarios.</td>
</tr>
<tr>
<td>Communicate patient status and needs to EMS personnel and a receiving facility to transfer care of patients in the instance of a unit or facility evacuation.</td>
<td>C, PC, SBP</td>
<td>Core</td>
<td>• Role play evacuation handover</td>
<td>• Direct observation of evacuation handover with feedback</td>
<td>Trainees should have access to, and they should practice using, a standardized template with information that needs to be provided to patients, EMS, and families in the event of patient transfer or evacuation.</td>
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<td></td>
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<td>• Standardized patients</td>
<td>• Standardized patient checklist</td>
<td>• Know how to access the hospital’s or practice’s disaster preparedness plan and review or practice this plan.</td>
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<td></td>
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<td></td>
<td>• Simulation</td>
<td>• Simulation checklist</td>
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<tr>
<td>Identify the institutional and local public health contacts in case of a disaster in which the trainee needs help (e.g., program director, on-call hospital administrator, state health department).</td>
<td>SBP, P</td>
<td>Core</td>
<td>• Reinforcement at resident or fellow meetings or retreats</td>
<td>• Module MCQs</td>
<td>Trainees should know the institutional, government, and public health contacts that may coordinate responses to natural disasters and how to contact them if needed.</td>
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<td>• Oral questions</td>
<td>Examples include the following:</td>
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<td>• Serving as a trainee member of a hospital committee to prepare a climate-related disaster plan and ensure trainees are considered in these plans and</td>
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<td>• Engaging with public health officials to learn about the generation of hospital disaster preparedness plans, especially during a research elective or summer experience.</td>
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<tr>
<td>Effectively collaborate with hospital or public health officials on climate-related disaster preparedness and/or response.</td>
<td>MK, C, SBP, P</td>
<td>Advanced</td>
<td>• Service on a hospital committee</td>
<td>• Participation on committee</td>
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<td></td>
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<td></td>
<td>• Public health elective</td>
<td>• Scholarly project outcome</td>
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<td>• Scholarly project work</td>
<td>• Experiential learning (elective)</td>
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</table>
### Participate in the planning, practice, or evaluation of evacuation and transfer exercises as part of hospital disaster preparedness plans.

- **MK, C, SBP, P Core**
  - Experiential learning (practice)
  - Service as a committee member for disaster drill planning
  - Participation in hospital drill
  - Participation on committee

Examples of resident involvement in disaster drills include the following:
- Reviewing patient lists to identify patients who are safe for discharge home,
- Prioritizing patients for transfer,
- Reviewing roles and responsibilities of team members and outlining a pathway for safe evacuation of a list of patients in the absence of power and electronic medical records, and
- Communicating updates to patients’ family members.

---

### Advocate and participate in activities that advance low- or no-carbon solutions in the provision of health care and the practice of medicine.

- **MK, C, SBP, P Advanced**
  - Advocacy rotation or elective
  - Health care administration or business of medicine elective
  - Committee member for health care sustainability
  - Sustainability quality improvement project

Examples of ways to promote cleaner air and reductions in greenhouse gases include the following:
- Writing a letter to the editor in support of carpooling and greater utilization of public transportation to decrease carbon footprint,
- Advocating institutional commitments to decreasing greenhouse gas emissions and participating in quality improvement projects on this topic (e.g., energy efficiency, waste reductions, power purchase agreements),
- Advocating sustainability initiatives that promote healthier, greener activities for employees (e.g., public transportation, bike paths), and
- Advocating plant-based menu choices in the cafeteria.

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### Appendix 1 (Continued)

#### Learning objectives | ACGME competencya | Core or advanced objectiveb | Learning formatsc | Assessment strategies | Curricular points and notes
---|---|---|---|---|---
Participate in the planning, practice, or evaluation of evacuation and transfer exercises as part of hospital disaster preparedness plans. | MK, C, SBP, P | Core |  | Participation in hospital drill | Examples of resident involvement in disaster drills include the following:
- Reviewing patient lists to identify patients who are safe for discharge home,
- Prioritizing patients for transfer,
- Reviewing roles and responsibilities of team members and outlining a pathway for safe evacuation of a list of patients in the absence of power and electronic medical records, and
- Communicating updates to patients’ family members.

Advocate and participate in activities that advance low- or no-carbon solutions in the provision of health care and the practice of medicine. | MK, C, SBP, P | Advanced |  | Review of written advocacy communication | Examples of ways to promote cleaner air and reductions in greenhouse gases include the following:
- Writing a letter to the editor in support of carpooling and greater utilization of public transportation to decrease carbon footprint,
- Advocating institutional commitments to decreasing greenhouse gas emissions and participating in quality improvement projects on this topic (e.g., energy efficiency, waste reductions, power purchase agreements),
- Advocating sustainability initiatives that promote healthier, greener activities for employees (e.g., public transportation, bike paths), and
- Advocating plant-based menu choices in the cafeteria.

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**Abbreviations:** ACGME, Accreditation Council for Graduate Medical Education; MCQs, multiple-choice questions; COPD, chronic obstructive pulmonary disease; OSCE, objective structured clinical examination; and EMS, emergency medical services.

*The 6 ACGME core competencies are, in the order they appear here, medical knowledge (MK), patient care (PC), interpersonal and communication skills (C), professionalism (P), practice-based learning and improvement (PBL), and systems-based practice (SBP).

*Some activities can be considered core knowledge at a fundamental level and are amenable to in-depth learning as an advanced knowledge or skill for interested trainees.

*Many learning objectives could be delivered in multiple formats and integrated into existing activities. Suggested formats are those that could be implemented to provide consistent delivery of material and experiences to all residents.

*Adaptations for clinical practice entail the following: identifying and treating climate-related illnesses; obtaining and integrating patient- and location-specific climate risks into plans for disease prevention and treatment; and effectively communicating information to and collaborating with patients, families, and other health professionals.

*Implications for health care delivery entail the following: working within local and regional medical and public health systems on preparing for and responding to the health effects of climate changes and climate-related disasters and advocating changes at the patient, institution or practice, and policy levels to promote a healthier environment.