National Institute of Environmental Health Sciences

Educational Materials

A Clinical Health Care Student Exploration of the Impacts of Climate Change on Human Health in the United States

CLINICAL CASE STUDIES FOR STUDENTS AND HEALTH PROFESSIONALS

The following examples are included to help students and clinicians explore in more detail the health impacts of climate change and provide real-world examples and case studies.

Adopted and modified from: Luber, G. and J. Lemery (2015). *Global climate change and human health: From science to practice*. John Wiley & Sons.

Extreme Heat:

Health care spending, heat and care for the elderly:

In 2009, the number of persons over 65 years of age in the United States numbered 39.6 million, representing 12.9% of the total population. The elderly demographic is expected to rise to 72.1 million by 2030. Elderly populations have unique health needs that are likely to be exacerbated with rising ambient temperature and therefore must be considered as we make projections of future health care costs. Human mortality has been shown to increase on hot days, often attributed to cardiovascular and respiratory collapse, and the elderly are disproportionately affected for medical as well as social reasons.[i] Aging is associated with a decreased physiologic ability to compensate to heat, especially when concurrent chronic and degenerative disease exists. Cognitive disability compounds these factors by altering risk perception and protective behaviors.[ii] The trend in increasing mortality among the elderly exists worldwide.[iii] The financial cost of caring for an aging population is daunting, as Medicare spending currently represents 14% of the federal budget ($492 billion)[iv] and is expected to increase by two-thirds in the next ten years. With projected increases in extreme heat events and other natural disasters, the needs of the elderly are likely to be more than are projected by current estimates that do not account for climate change. Hospital administrations and clinicians must therefore prepare for this increased demand in services and curtail their systems-based practices to be able to meet the rising need with a limited financial budget.

Climate change poses unique risks to a rapidly growing demographic of elderly patients. Clinicians, hospitals, policy makers and financial planners must prepare for these current and future needs.

Individual risk and emergency readiness:

Epidemiological research shows that mortality in urban populations increases as the temperature rises.[v] Models have used mean temperature, maximum temperature, and humidity, as well as the time/rate of onset of these variables to predict when clinically significant heat waves may occur. These models allow for initiation of time-sensitive warnings to be released to the public. However, there is significant variability in the ways individuals are impacted; factors such as age, housing architecture, socioeconomics,

prevalence of chronic disease, and relative social isolation all play a part. Thus, each demographic has a different threshold at which heat-related illness becomes clinically apparent. Emergency medical systems (EMS)[vi], nurse lines, and emergency departments[vii] are at the forefront of detecting and treating heat-related illnesses. Research has shown that reliance on these organizations increases with rising temperatures, and the public's reliance on these institutions could therefore be an accurate indicator of the appearance of clinically relevant heat related disease. More research is needed to determine real-time surveillance data generated from these clinical settings could assist public health officials in deciding when to issue heat warnings to a given community. Early warnings can help to ease the toll of heat-related illness and prevention may ease the burden of such events on the health care system.

Integrating weather modeling and public health intervention to address vulnerable populations may ease the burden of heat stress on individuals and the health care system.

Vulnerable populations: Poverty and extreme heat events:

Poverty is an independent risk factor for illness related to heat. Poverty is associated with a decreased likelihood of access to medical care. It is also associated with decreased access to protective measures, such as air conditioning,[viii] which is then compounded by the urban microclimate that escalates heat events through "heat island" effects.[ix] The heat island effect, caused by nighttime radiation of heat from buildings, industrial heat production, and a lack of green spaces, elevates both daytime and nighttime temperatures in inner city neighborhoods.[x] This effect is evident in analysis of casualties from heat events in Pheonix, Arizona[xi] and Chicago, Illinois in 1995[xii], when a disproportionate amount of deaths occurred among inner city poor. These figures highlight the need for the medical community to increase healthcare access and address environmental health disparities in the inner city.

Resources are needed to address environmental disparities and provide protective measures against heat related illness in the inner city.

Energy security and integrative approaches to heat stress in the developing world:

Air-conditioning has become the mainstay approach to buffer the deleterious health effects of extreme heat events. Unfortunately, air conditioning in and of itself places major strains on energy supplies and contributes substantially to CO2 emissions which in turn increase global surface temperatures. Eighty-percent of energy for air-conditioning comes from fossil fuels and according to estimates, total world air conditioning consumes roughly 1 trillion kilowatt hours annually, more than twice the total energy consumption of the entire continent of Africa.[xiii] Given the necessity of cooling, both now and in the future, essential energy infrastructure planning must begin now. The rapidly transforming developing world contains 38 of the largest 50 cities on the planet, the warmest of which are in the developing world.[xiv] We can anticipate that under warming conditions, the energy needed to keep these populations safe will be exponential. Thus, to curb the health effects of heat stress among vulnerable populations in a sustainable and energy-wise way, city planners and engineers must creatively utilize energy-saving technologies as well as integrate traditional technologies that have a small energy footprint. These

designs include passive cooling systems (evaporative cooling[xv], night flushing[xvi] and passive downdraft evaporative cooling[xvii]), exterior heat sinks, and modification of existing structures with awnings, reflective paint, and landscaping that maximizes shade. Health care organizations should model appropriate building codes and use of indoor climate control to model climate-literacy, to save costs and to achieve energy security.

Rapid warming as well as rapid development are occurring in the developing world. To keep populations safe-guarded against the negative effects of extreme heat, innovative cooling solutions are necessary.

Heat waves and primary care:
During the 2003 heat wave in Europe, an estimated 30,000 individuals succumbed to heat death. A majority of the 30,000 deaths were among the elderly, who remained alone in their homes despite warnings to seek cooler environments.[xviii] The elderly are particularly vulnerable to heat waves as their mobility, hearing, vision and/or cognition may be compromised, making it difficult or impossible for them to process and/or adhere to warnings. Cardiovascular, renal and pulmonary diseases, which disproportionately affect the elderly, compound cognitive and mobility issues and thus increase vulnerability during heat waves. Primary care physicians can begin to incorporate “heat vulnerability” in their preventative health screening as a way to raise awareness among this population of the early warning signs of heat stress.

Elderly populations are particularly vulnerable to heat stress, a factor that should be incorporated into routine care.

Outdoor Air Quality:

Disparities in pediatric asthma:
The Centers for Disease Control and Prevention report that asthma prevalence increased from 7.3% in 2001 to 8.4% in 2010, thus affecting 25.7 million individuals annually.[xix] Children constitute a disproportionate majority of this statistic. It has been shown that children living in poverty experience higher rates of asthma across all ethnic groups compared to higher income households.[xx] Children of low-income families and racial minorities also manifest more severe disease than white, higher income children.[xxi] One explanation for this finding is that children in living in low-income environments are subject to substandard housing with more triggers such as mold, rodents and cockroaches. In addition, families often are forced to go without preventative medicines and heating/cooling in order to save money, which leaves children vulnerable to attacks. Deteriorating air quality due to climate change is a concerning threat to children in low-income, inner-city environments. Clinicians, regulators, public health officials and housing authorities must come together to address this large and vulnerable population.
Deteriorating air quality threatens the health of vulnerable pediatric patients, especially among those living in low-income environments.

Ozone: a threat-multiplier:
Acute and chronic ozone exposure has been associated with significant adverse health effects in humans, including cardiopulmonary and respiratory morbidity and premature mortality.[xxii] Abrupt daily increases in ozone concentrations have been shown to decrease pulmonary function[xxiii], increase asthma exacerbation rates and increase emergency department visits.[xxiv] Ozone has also been associated with an increased relative risk of death from all cardiopulmonary causes.[xxv] A recent assessment found that as many as 2,500 ozone-related premature deaths, 3 million cases of acute respiratory symptoms and one million school days could have been avoided annually could the nation attain the 75 ppb standard goal.

Ozone not only compounds global warming but also causes measurable negative health effects during periods of acute increase.

Compounding health effects of carbon-based energy:
Fine particulate matter, generated through the burning of fossil-fuels in industrial processes and the transportation sector have been shown to cause negative acute and chronic health problems. Studies show that elevations in ambient particulate matter are associated with increases in ST-elevation myocardial infarction and accelerated atherosclerosis.[xxvi] Other studies show that each 10-µg/m3 elevation in fine particulate air pollution is associated with approximately a 4%, 6%, and 8% increased risk of all-cause, cardiopulmonary, and lung cancer mortality, respectively.[xxvii] These increases in severe, acute disease have large impacts on emergency departments and health care systems.

Ambient fine particulate matter, produced as a byproduct of fossil fuel combustion, significantly negatively impacts human health which in turn impacts health-care system usage.

Flooding:

Case study: Hurricane Sandy:
The closing of Bellevue hospital in New York City in the wake of the flooding caused by Hurricane Sandy highlights the need to intensify resources in inner-city, climate-vulnerable areas. Bellevue Hospital is the largest public hospital in the city, with 828 inpatient beds and multiple clinics that handle nearly 500,000 outpatient and 145,000 emergency visits per year. More than 80% of Bellevue patients come from the city's medically underserved populations.[xxviii] When Superstorm Sandy hit New York on the evening of October 29, 2012, it caused power-outage throughout the hospital and severe flooding which ultimately forced the hospital to evacuate all patients and close its doors.[xxix] To make matters worse for patients, the hospital remained closed for three months after the storm. The effect that this closure had on city's most vulnerable populations is unknown. Those who relied upon Bellevue for intensive outpatient care or those requiring hospitalization would have had to travel outside their neighborhood on unreliable post-disaster public transportation to seek care from other already severely over-crowded hospitals. In retrospect, there were many aspects of Bellevue's design that were not prepared for a storm surge, despite its

location along the water.[xxx] This incident highlights the need to intensify resources in areas such as inner cities, which have high concentrations of at-risk populations and are vulnerable to natural disasters.

System-wide evaluation of public and "safety net" hospitals is needed to prepare for natural disasters.

Health-related exposures from heavy precipitation events:
Expanding areas of urbanization across the United States coupled with increasing extreme precipitation events pose significant threats to human health. During times of low precipitation, urban environments collect substances such as heavy metals, chemical pollutants, and pathogens on their impervious surfaces. When extreme precipitation occurs, treatment capacities of water facilities are overwhelmed and these chemicals and pathogens are released into surface, drinking, and recreational waters. It is estimated that 6%-40% of the 99 million cases of acute gastroenteritis that occur annually in the US can be attributed to contaminated drinking water. We know that more than half of contaminated drinking water outbreaks in the past sixty years have followed extreme rainfall.[xxxi] In addition to bacterial exposures, toxic substances such as copper, zinc, and lead, as well as pesticides and hormonally active compounds accumulate on roads, roofs, and parking lots and are released into the drinking and surface waters during extreme precipitation events, never even seeing a treatment facility. These substances have the propensity to create neurotoxicity and act as carcinogens when ingested.[xxxii] The individuals most at risk from these types of environmental contamination include children, the elderly, pregnant women and the immunocompromised. Physical factors that put communities at risk can be measured through indices such as the normalized built-up difference index (NDBI) and thus be used to target improvements in domestic water management.

Extreme precipitation events unleash toxic man-made compounds as well as infectious pathogens into drinking and recreational waters, posing significant risks to human health.

Flooding and environmental contamination:
Severe weather events are associated with flooding and release of toxins from contained sources that have the potential to enter the human food chain and affect food safety. For example, following the 2002 floods in central Europe, monitoring programs traced polychlorinated dibenzo-p-dioxins and dibenzifluranes from breached containers into soils and into the food chain via cow milk.[xxxiii] Floodwaters from Hurricane Katrina caused oil spillage from storage tanks as well as spillage of pesticides, metals and stored hazardous waste that were untraced and thus their impact unknown.[xxxiv] It is unclear what the significance these toxins is to human health, however it is a field that deserves further monitoring and intervention in order to ensure a safe food supply especially during disasters.

Contained industrial wastes are susceptible to being unleashed during extreme weather and flooding leading to release of toxins that have the potential to enter the food chain and adversely affect human health.

Climate refugees:

Extreme weather events have vast potential to displace individuals from their communities and homes. Such movement disrupts access to health care systems, and severs relationships between doctors and patients. In the wake of natural disasters, care for patients is frequently interrupted. Individuals struggle to find new providers while at the same time, doctors become overwhelmed by an influx of new patients who often arrive without medical records. Interruption of treatment may contribute to the high rates of acute exacerbations of chronic diseases such as end-stage renal disease, asthma, cardiovascular disease and chronic obstructive pulmonary disease in the wake of natural disasters.[xxxv][xxxvi]

Depending on the location of the disaster and the refugee mitigation efforts, the responsibility for care of displaced patients could be spread in unpredictable ways and in far-reaching locations as was seen in the aftermath of Hurricane Katrina in 2005.

Extreme weather and resulting human movements exacerbate chronic medical problems and the burden of treatment is spread unpredictably among health care facilities in surrounding areas.

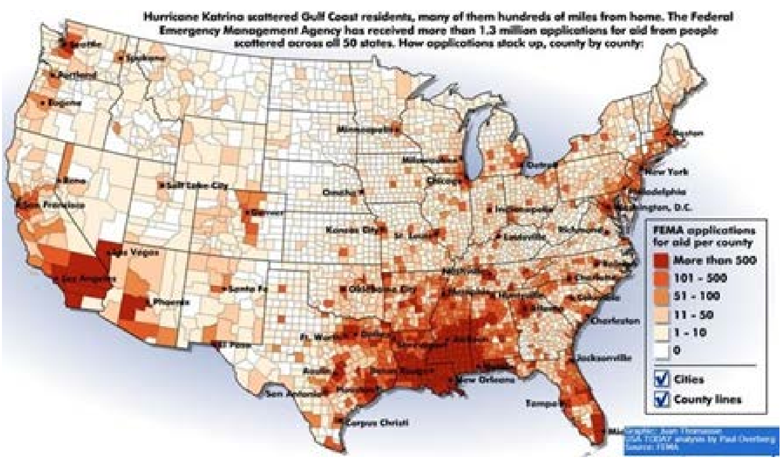

Photo Credit: [USA Today]() and Federal Emergency Management Agency

Case Study: Hurricane Katrina:

During natural disasters, hospitals are considered "custodial" organizations and thus are the last to be evacuated and closed. During Hurricane Katrina, floodwaters surrounding area hospitals stranded 2,000 patients and 5,500 staff and family.[xxxvii] The hospitals had no electricity, as backup generators in basements were underwater. There was no running water, sewage treatment, refrigeration or access to CT scanners, X-rays, laboratory information, or blood banks. Ventilators and dialysis machines could not function. Essential supplies dwindled due to transportation breakdown. Reports describe emergency surgery being done by flashlight with little or no anesthesia and family members fanning patients in sweltering rooms.[xxxviii] Many hospitals were short-staffed and providers worked long shifts in adverse conditions while witnessing the inevitable deaths of patients who would not be sustained without life support.[xxxix] How should we prepare for sudden or prolonged resource shortage? Over the past fifty years, modern medical practice has become increasing dependent upon technology in diagnostics and treatment, and health care is one of the most "energy intense" sectors of the economy.[xl] Hospitals can

prepare for resource shortage by adopting green, energy saving practices, by identifying through institutional analysis, what essential systems are necessary in emergency scenarios and how to shunt limited power to those areas. Health care providers can and must begin to train themselves to practice medicine without intensive technology or essential diagnostic testing. This approach will not only prepare us for disasters related to the environment but also abate the current financial healthcare crisis.

Health care is currently one of the most energy-intense sectors and its systems become vulnerable during natural disasters when resources become scarce. Hospitals and providers can prepare by adopting green infrastructure and limiting unnecessary testing and interventions in the present.

Vector-Borne Diseases:

Preparing for change: Malaria early warning systems:

The transmission of malaria through *Anopheles* mosquitoes is strongly linked to climate conditions. Predicting epidemic outbreaks of malaria in relation to environmental conditions has therefore become an area of intense research. Malaria early warning systems combine elements of early detection of epidemics (case surveillance), early warning (based on monitoring meteorological data) and long-range climate modeling.[xli] As opposed to endemic malaria, which occurs in populations that have some immune resistance to the parasite, epidemics occurring in immune-naïve communities have more disastrous health consequences with higher rates of morbidity and mortality. The health impacts of accurate prediction of epidemics appear promising. A recent model developed by Thompson and colleagues is able to predict epidemic occurrence with reasonable certainty with greater than one month and at times five-month lead time.[xlii] Advocates for early warning systems urge that precise prediction models give policy makers and health officials the time necessary to protect vulnerable populations in proactive versus reactive way. The question now is whether the models are sound enough to put into practice and if policy makers are willing to respond.

Malaria early warning systems combine case surveillance with long-range climate modeling to allow clinicians and policy makers to proactively prepare for outbreaks and allocate resources.

West Nile Virus surveillance: Lessons from the 2012 Epidemic in Dallas, Texas:

West Nile is a mosquito-transmitted, climate-sensitive disease that causes a spectrum of illness from a viral syndrome to severe neuro-invasive disease.[xliii] After a period of relative dormancy in the continental United States, it made an epidemic comeback in Dallas County in 2012. In the months prior to the epidemic, researchers in Dallas County regularly checked dispersed mosquito traps, monitoring the local "vector index," an estimate of the prevalence of West Nile virus-infected mosquitoes.[xliv] Historical reference informed a threshold index after which clinical cases of infection would likely appear. This threshold was crossed in May of 2012, and warnings were issued to area physicians to be on high alert for viral syndromes associated with neurologic complaints. Increased testing resulted and the first cases were detected in early June. Although systems accurately predicted the epidemic, aerial spraying did not

commence until August 2012, when the bulk of infections had already occurred and death rates began to escalate. What caused this delay was likely prolonged laboratory testing times to confirm diagnosis and delays in action on behalf of public health officials, perhaps secondary to unfamiliarity with the validity of early detection systems. Physicians and health officials must work more closely in the future to make better use of surveillance systems to orchestrate timely responses and avoid unnecessary morbidity and mortality.

Surveillance programs for West Nile are soon to be sensitive enough to predict outbreaks of disease. Clinicians and public health officials must increase their cooperation and communication to bring this knowledge to meaningful place in clinical practice.

Human migration and vector borne illness
Climate change is likely to cause mass movements of people - from rural areas into urban zones, as well as migrations across country lines in response to changes in resource availability. Therefore, clinicians world-wide must have a high index of suspicion for the appearance of non-endemic diseases. For example, the West Nile virus first made its appearance in Uganda in 1937 and then spread to Tunisia and Israel before appearing in New York City. The spread of this virus, as well as others such as Ebola and avian influenza A (H5N1) exemplify the interconnectedness of our environment and highlight the need for international communication about the appearance of infectious vector-borne diseases.

The impacts of climate change on the geographic distribution of resources may result in mass human movement. Clinicians and public health officials must be alert to the possibility of infectious diseases appearing in unexpected places.

Climate and Zoonotic disease transmission
Zoonotic pathogens account for 61% of all infectious pathogens and 60% of emerging infectious diseases.[xlv] Anthropogenic land use patterns, climate change, hydrologic cycle changes and urbanization influence transmission of these pathogens by altering ecologic niches of the vector and host, by changing community structure, and by altering behavior of vectors, hosts and humans.[xlvi] Such complexity makes it difficult to predict whether changing climates will lead to increased or decreased disease incidence.[xlvii] What we do know is that immunology and physiology play a large role in determining the severity of infection as well as its further transmission. Poor nutrition, environmental stress and prior immunologic exposure all contribute to the robustness of the human host’s defense and determine parasitic, bacterial and viremic loads and thus how contagious a patient will become.[xlviii] Malnutrition and chronic diseases are widespread in both the industrialized and developing world and thus play an integral part in the spread of zoonotic pathogens.

The manifestation of disease from climate sensitive zoonotic pathogens is influenced by the baseline health of communities and individuals which may in turn be threatened by climate change.

Water-Related Infection:

Impacts of cryptosporidium on immunocompromised patients:

Cryptosporidium is an ubiquitous and tenacious organism that is highly resistant to conventional means of disinfection (chlorination and filtration) owing to its small size (4-6 micrometers) and cystic structure.[xlix] Despite even stringent standards for water turbidity in wastewater treatment facilities, outbreaks still frequently occur.[l]

In developing countries *Cryptosporidium* accounts for 6.1% of cases of diarrhea in HIV-negative patients and 24% of cases in HIV-positive patients, while in developed countries it causes 2.1% and 13.8% of illnesses respectively.[li] In the immunocompromised population it can often be a fatal disease.[lii] Even when not fatal, infection may also cause dire yet subtle complications. Among children living in impoverished areas, infection has been shown to lead to impaired weight gain in the month following symptomatic and even asymptomatic infection, which occurs without a subsequent "catch up" growth period.[liii] Among patients with chronic diseases, infection has been observed to interfere with the absorption and therapeutic levels of anti-retroviral and anti-tuberculous drugs,[liv] which can affect the transmission of these highly communicable diseases.

Cryptosporidium is a common climate-sensitive disease that health care providers must be aware of in order to prevent complications among vulnerable patients.

How safe is our water supply?

In 2012, the World Health Organization announced attainment of the Millennium Development Goal (MDG) of reducing the number of individuals without "sustainable access to safe drinking water" by half. One major information gap that remains regards the *quality* of the water. Even in the best of public water treatment scenarios, outbreaks of water-related disease still occur.[lv] In a recent study conducted by the UNICEF and USAID, households were questioned in regards to their drinking water access. As a proxy for "sustainable access to safe drinking water," individuals were asked if they had "use of an improved water source," where "improved" was generalized to imply only a mechanism of handling water that aimed to decrease the likelihood of it causing disease or infection.[lvi] Since there is no agreed definition of "safe" and no widely used and inexpensive means of testing drinking water for pathogens, it is difficult to predict if attainment of this MDG will result in a decrease in the global burden of gastrointestinal disease. In addition, we are at this point unable to predict with regional certainty the effects of climate change on local water access. Medical personnel will likely be at the forefront of monitoring this impact.

Access to safe water is a difficult milestone to achieve, define and assess. It is requisite to achieve modern health standards and may be threatened by changing climates.

Health implications of Harmful Algae Blooms (HAB):

Climate change is leading to more frequent and widespread HABs thus increasing the incidence of human exposures. The impacts of HABs are diverse and may affect both coastal and inland communities. For example, *Kareina brevis,* the dinoflagellate responsible for Florida's red tide,[lvii] blooms on an annual basis with varying degrees of intensity.[lviii] The cells of these organisms contain potent neurotoxins, which when lysed by wind and waves become aerosolized and can travel up to a mile inland.[lix] Studies have linked the blooming of these algae with upper and lower respiratory symptoms including rhinorrhea, cough, and bronchoconstriction, especially in asthmatics and the elderly. High intensity blooming events have been shown to correlate with increased emergency department usage in nearby coastal areas.[lx] Climate change and resulting changes to oceans may increase the intensity and occurrence of HAB's, the costs of which include exacerbation of chronic illness, and increased volumes of patients in emergency departments.

Harmful algae blooms pose significant risks to communities and health care systems. Strong public health monitoring is needed to trace these impacts and create notification pathways within the health care system and within communities.

Food and Nutrition related impacts:

Amplification of repercussions from infection on nutrition:

Experts estimates that one third of the world population is infected with some form of intestinal helminth parasite at all times.[lxi] Helminth infections have been correlated with impaired physical and cognitive growth and development in children.[lxii] *Ascuris lumbricoides*, *Trichuris trichiuru*, *Schistosoma* species, and other hookworms colonize the intestinal lining. Colonization prevents the absorption of nutrients and causes a chronic inflammatory state, diarrhea, and blood-loss anemia.[lxiii] Helminth life cycles involve periods of dormancy in the environment and are likely to be impacted by changing global climates. Researchers propose that either the infection itself or the secondary manifestations of malnutrition, stunting, and anemia have effects on cognition and learning among infected children[lxiv]. These findings bring urgency to the need to develop proper treatment and surveillance of infections among communities living in poverty. Most public health programs have targeted infection through improved hygiene and handling of food and human waste, and/or through chemotherapeutic drugs. Recently, studies looking at the effects of improved nutrition suggest that dietary intake of micronutrients such as vitamin A, vitamin B12, vitamin C, riboflavin, zinc, selenium, and iron all have immunomodulating functions[lxv] and may impact the course of parasitic disease.[lxvi][lxvii] Thus, a positive feedback situation emerges whereby dietary malnutrition increases risk for parasitic infection, which itself furthers the extent of the malnutrition through malabsorption. A new clinical approach towards eradication of infection could focus on intervening in micronutrient deficiencies while at the same time employing the use of chemotherapeutic agents and public health measures.

Helminth infections are a prevalent climate sensitive illness that has wide-reaching implications for human health and nutrition.

Food scarcity and agrochemicals:
Climate change and population growth are increasing demands on the global food supply and increasing reliance upon industrialized food production and agricultural chemical use. Research into the long-term health effects of pesticide use lags decades behind widespread utilization of these compounds. Large studies of the chronic effects of pesticide exposure on children's health have shown links to birth defects, premature birth, intrauterine growth restriction and several childhood cancers.[lxviii] Many pesticides currently in use are classified as carcinogens by the United States Environmental Protection Agency. Expert consensus now holds that there are links between pesticide exposure and neuro-cognitive development.[lxix] Prospective studies link early-life exposure to reductions in intelligence quotient and increased rates of attention-deficit/hyperactivity disorder and autism.[lxx][lxxi] Unfortunately, there is currently no information on developmental toxicity of over 80% of the 3000 chemicals used in US agriculture.[lxxii] And yet neurodevelopment disorders such as autism, attention-deficit disorder and pervasive development disorder now affect one in six children living in the industrial world.[lxxiii] More research is necessary to untangle the myriad of connections between early life exposure and pesticide toxicity and create regulations that address the severity of the clinical implications of exposure to ensure a safe food supply as we rely more upon industrialized food.

Climate change leads to food insecurity, more reliance on industrialized food production and the use of chemicals with unknown and known detrimental effects on human health.

Climate preparedness: Food Security
Climate change is anticipated to have far reaching impacts on food production and certain aspects of food quality.[lxxiv] Currently, one-third of children in developing countries are malnourished by anthropometric standards. It is essential use an evidence-based approach to understand why current systems are failing as researchers and policy makers attempt to stabilize food security. Central America has the highest prevalence of stunting (23%) and the lowest rates of improvement over the past 25 years, while nearby South America has lower levels stunting and the highest rates of improvement, despite economic stagnation in both regions.[lxxv] A recent Lancet series analyzes how and why nutrition programs fail, and reports that some failures can be traced to a lack of political commitment, while others can be traced to failure to support programs that have evidence-based results.[lxxvi] What public health professionals and clinicians can learn from this is that malnutrition is knowable and treatable and that with proper programs, we have the tools to address the issue. Clinicians must serve as spokespersons in their local political arena to advocate for evidence-based nutrition programs.

Evidence-based approaches should be used to assess and address the health impacts of food security among vulnerable populations.

Climate change and food scarcity:
Global climate change is forecasted to intensify global food shortages in vulnerable places. The effects of chronic undernutrition range from physical to cognitive. On a worldwide level, growth stunting, severe wasting and intrauterine growth retardation together contribute to 2.2 million deaths annually, accounting for 35% of mortality of children less than five years of age.[lxxvii] Malnutrition has been shown to lead to impaired cognitive development, learning disability, deferment of education, attrition from the work force and less decreased lifetime earnings.[lxxviii] Micronutrient deficiencies are pervasive as well and are likely to intensify. Iodine deficiencies result in goiter, hypothyroidism, and developmental disabilities including severe mental retardation. Insufficient intake of vitamin A is the leading cause of blindness worldwide. Dietary iron deficiency leading to anemia is worsened by chronic parasitic infection and chronic illness that so often accompanies it in resource-poor settings. Folic acid is essential for normal nervous system development, yet is often lacking in diets along with zinc, and both are linked to childhood growth stunting.[lxxix]

Health effects of chronic undernutrition manifest in a myriad of ways, ranging from physical to cognitive, and are likely to intensify in the future as a result of climate change.

Ciguatoxins: health effects of a climate sensitive toxin
Ciguatera toxin is one of the most common non-bacterial causes of fish-related food poisoning in the United States.[lxxx] The disease is caused by consumption of certain tropical reef fish which bioaccumulate toxins from the algae *Gambierdiscus toxicus*. Although most cases are limited to the algae's geographic range of Florida and Hawaii, changing marine climates could have unpredictable effects on algae populations and cases of disease could rise. In addition, specialty fish are often shipped around the country causing the disease to manifest outside its endemic range. Therefore, it is important for health care providers to be able to recognize the symptoms of poisoning. Ciguatoxin is a heat and acid stable, odorless, tasteless[lxxxi] compound that causes hyperpolarization of sodium channels in an array of tissues,[lxxxii] leading to a broad array of neurologic symptoms. Common manifestations include paresthesias, numbness, headache, ataxia, vertigo, weakness, paralysis and cranial nerve dysfunction.[lxxxiii] Gastrointestinal symptoms and hemodynamic instability also occur. Treatment is supportive, yet effects may last weeks. The differential diagnosis for Ciguatoxin poisoning includes paralytic shellfish poisoning, stroke, eosinophilic meningitis, organophosphate poisoning, tetrodotoxin poisoning and more. Clinicians must take a careful history to uncover this rare yet important cause of climate sensitive bio-poisoning.

Ciguatera poisoning is a climate sensitive cause of bio-poisoning that clinicians must be aware of.

The global nutrition transition, "dual-burden disease" households, and climate change:
Global climate change directly impacts agriculture and the cost and availability of food. Stark differences exist between rich and poor nations in terms of the prevalence of various diseases; communicable diseases and malnutrition predominate in developing countries whereas non-communicable diseases such as diabetes, cancer, and cardiovascular disease are more common in developed countries.[lxxxiv] However, this phenomenon is rapidly changing in low to middle income countries, where there is now a trend towards the existence of both types of disease within the *same household*.[lxxxv] Malnourished children live alongside mothers who suffer from obesity, diabetes and cardiovascular disease, causing a "dual-burden." The current nutrition transition is a shift from a diet rich in legumes, vegetables and coarse grains, which have low carbon-foot print, to a diet high in refined carbohydrates, sugars, fats, and animal-source foods. The forces shaping this transition are thought to be food prices, demographic shifts from rural to urban life-styles, the commercialization and packaging of food, as well as life-style changes in developing regions.[lxxxvi] Researchers forecast that the impact of this transition will be epidemic levels of obesity throughout the world. From 1988 to 1998 alone, the prevalence of obesity increased from 2.3% to 19.6%.[lxxxvii] Estimate predicts that by 2030 there will be approximately 2.16 billion overweight and 1.12 billion obese adults.[lxxxviii] The obesity epidemic will take a tremendous toll on health care systems in transitioning countries. Providers will have to shift their expertise and resources towards caring for the co-morbidities associated with obesity, such as diabetes and cardiovascular disease, while at the same time addressing the needs of those suffering from diseases related to communicable diseases and malnutrition.

Global climate change is affecting food availability and lifestyle choices, thus shifting the prevalence of diseases worldwide.

Mental Health and Well-being:

Climate and mental health and recovery:
According to the World Health Organization (2011), mental, neurologic and substance use disorders account for 14% of the global burden of disease. Current estimates place the global shortage of mental health care workers at 1.8 million, including 55,000 psychiatrists, 628,000 nurses and 493,000 psychosocial care providers.[lxxxix] The rippling effect of mental distress caused by natural disasters can be observed in increased rates of substance abuse,[xc] post-traumatic stress disorder,[xci] child abuse[xcii] and suicide.[xciii] These conditions have the potential to undermine the social fabric of a community in which a natural disaster has occurred, impairing reconstruction efforts and economic resolution. Additionally, these mental health disorders may further manifest as disease through their protean interactions with physical health.[xciv] Although regions of the world with a disproportionate dearth of trained mental health work force are likely to experience a greater impact, industrialized nations are not immune. Currently, the United States spends a relatively low percentage of total health care dollars on mental health. Studies have identified a widespread prescribing and non-prescribing provider shortage,[xcv] which has resulted in "defacto" mental health care, whereby roughly primary care doctors or sub-specialty practitioners care

for 50% of patients seeking treatment for mental health disorders. Thus, as the mental health burden from natural disasters rises, all areas of medicine are going to be called upon to care for patients in need, with little funding or systems in place to do so.

Mental health care plays a crucial role in disaster recovery and the dearth of providers domestically and globally means the care will be distributed among all specialties of medicine.

Trauma and mental health – increasing surveillance of disaster impacts:
Natural disasters can result in significant physical and emotional trauma. The symptoms of trauma can be expressed in many forms, which may complicate accurate clinical diagnosis and compound existing medical co-morbidities, especially chronic pain. Some experts in the field of trauma have begun to unravel the ways in which culture informs the expression of psychological distress. The Harvard Program for Refugee Trauma has employed behavioral health specialists to design unique screening tools for six different countries in order to detect post-traumatic stress disorder (PTSD) in various cultures. They have found in many cases that neurologic, somatic and visceral pains become physical manifestations of psychological trauma. The severe pain that patients report is a real experience for them, regardless of any “organic” cause recognized by western medicine. Experts point out that a large barrier to patient treatment is the fact that health care professionals often shy away from asking patients about their history of trauma because they “believe they won't have the tools or the time to help survivors once they've elicited their history.”[xcvi] However, this history is imperative and will possibly become more so in the future. Recent studies through the Veteran’s Administration have shown value of proper identification and treatment of PTSD. It is estimated that up to 70% of veterans that live with chronic pain have PTSD, and up to 80% of those with PTSD suffer from refractory chronic pain. [xcvii] Research has shown that treatment of PTSD statistically lowers a patient’s perception of pain,[xcviii] thus improving quality of life and decreasing dependence upon narcotic pain medications. To prepare for the future and to better handle the already heavy burden of trauma in our society, medical schools and professional organizations can design curricula to incorporate practical education on detecting, discussing and managing trauma.

Climate change has the potential to result in widespread physical and psychological trauma. Thus, clinicians must be well versed in properly diagnosing and treating stress syndromes.

Stress and physical health: Implications for current and future generations:
“Stress” is a common complaint in our society. It may be conceived of as the passing of a mental, emotional or physiological threshold, after which a person can no longer cope and adapt.[xcix] On a physiologic level, stress is mediated through the production of the hormone cortisol in the adrenal glands. Higher levels of cortisol have been correlated with poor physical health, manifested through decreased immune function, high blood pressure[c], reproductive disturbances[ci] and more. In an era of global climate change, stress levels are expected to be rising due to the real and perceived threats of drought, famine, severe weather, over-population, forced migration, and more. As an example, in a study of Kenyan farmers subject to drought conditions, cortisol levels were found to be significantly elevated.[cii] In another

study, unemployment and job insecurity were found to impact the neuroendocrine and immune systems.[ciii] Even perceived stress may have negative health implications. In one study, participants who reported that stress was impacting their health were found to be twice as likely to suffer a heart attack as those who believed that stress had no effect on their physical wellbeing.[civ] Higher stress levels have implications for current as well as future generations. For example, women living in war-torn regions of the Democratic Republic of the Congo experience high levels of stress during pregnancy that may directly influence birth weight and lead to epigenetic modification of the glucocorticoid receptor NR3C1 of the infant.[cv] These epigenetic changes could impact how the child responds to stress and thus impact their long-term health profile. Clinicians will be faced with these health implications of stress at all levels of care and must learn how to advise patients.

Climate change causes real and perceived threats of food scarcity, job insecurity, natural disasters and more. Stress has wide-reaching effects on health that clinicians must be able to promptly and accurately diagnose and treat.

Recovering the psychologic fabric of a community:

When major disasters create psychosocial trauma, individuals and relational structures among communities and families have the potential to become strained. Research has examined the prevalence of stress disorders following disasters and found that not all individuals are affected equally. While many experience acute stress immediately following events, only some go on to develop long-term and debilitating conditions.[cvi] Furthermore, despite the negative connotations of stress, some investigations have found that when individuals are able to adapt after trauma, that new opportunities, deeper compassion for others, and strengthened spirituality can be the rewards.[cvii] What factors contribute to an individual's ability to adapt and evolve? Researchers have found that communication and trusting relationships may counters feelings of helplessness and meaninglessness in the setting of trauma.[cviii] Therefore, perhaps disaster management must encompass mechanisms to nurture stronger community ties as a way to instill resilience. Landau and Saul outline the following helpful themes for building community in the wake of a disaster: (1) Enhance social connectedness and information and resource sharing (2) encourage involvement in collective storytelling and validation of the trauma and response with the goal of "shared meaning" (3) re-establish the rhythms and routines of life and engage in collective healing rituals (4) arrive at a positive vision of the future with renewed hope.[cix] Healers and leaders can work within their communities in order to foster these processes at many levels by raising awareness, arranging community meetings, and nurturing an open and compassionate attitude towards distress in others.

Mitigation of climate-related disasters must consider the psychological effects that trauma has on communities. Clinicians and other community leaders can serve as leaders in rehabilitation efforts.

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