The Planetary Health Report Card: Literature Review by Metric

This literature review collates the evidence behind each of the metrics in the Planetary Health Report Card. It serves as a collection of references for further learning and a resource for those advocating for increased planetary health engagement at their institutions.

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Planetary Health Curriculum

1. **Did your medical school offer elective courses (student selected modules) to engage students in Education for Sustainable Healthcare or Planetary Health in the last year?**

Given the substantial impacts that climate change, biodiversity loss and increased air pollution will have on human health[1], it is imperative that medical schools begin preparing students for a changing world[1, 2]. The World Health Organization predicts that there will be 250,000 additional deaths each year attributable to climate change by 2030, and this is a conservative estimate, not accounting for many causal pathways[1]. Countries, governmental organisations, and health associations have all recognised the need to prepare healthcare providers to address the impacts of climate change[1]. The majority of medical schools, however, have not kept pace with these changes[1].

2. **Does your medical school curriculum address the relationship between extreme temperature health risks and climate change, as well as the socioeconomic/racial disparities in extreme heat exposure?**

As the climate warms, the frequency and intensity of heat waves are expected to increase, which is worrying as extreme heat waves have been associated with increased heat-related deaths, aggression, suicidal ideation, and hospitalisations for mental illness[3-5]. Heat waves have also been associated with salmonella outbreaks and are likely to increase the rates of certain chronic diseases by decreasing recreational, outdoor activity. Additionally, as the climate warms, air conditioning may become more expensive, and may need to be present over a much greater area, which could increase energy usage and make it harder for the elderly to prevent heat stroke[6].

In the United States, living in the inner city – areas often subject to becoming heat islands because of poor urban planning[4] – is an important risk factor for experiencing heat stroke during extreme heat events[3, 7]. Low-income groups have also been shown to have a higher instance of heat mortality, likely compounded by underlying factors such as obesity, mental illness, inadequate housing, and chronic disease[3, 6]. Other risk factors that have demonstrated an increased risk for heat-related mortality include occupational heat exposure, living in rural and remote communities, participating in strenuous activities, and having poor English language skills[4].

It is also true that the majority of countries most affected by climate change are developing nations, who are more vulnerable to extreme weather events and are in regions of the world more prone to them[8]. For example, in 2019, the countries most badly impacted by climate change were Mozambique, Haiti and the Bahamas, as measured by a "global climate risk index"[8]. However, it's also worth noting that this index downplays the effects of heatwaves and drought due to their longer period of effect (i.e. by damaging food supplies rather than causing deaths), and thus the potential impact on developing nations is exceptionally high[8].

3. **Does your medical school curriculum address the impacts of extreme weather events on individual health and/or on healthcare systems?**

Climate change is likely to directly impact healthcare systems and facilities[6, 9]. Facilities may experience structural and equipment damage from flooding, and may have challenges adapting to heat waves because of specific safety protocols such as restricted window opening[9]. Healthcare systems will also be burdened by a higher frequency of heat waves, which lead to heat-related mortality and have been associated with increased admissions for respiratory illnesses[9] and mental illness[5], along with increased emergency department use and ambulance call out rates[9]. Additionally, the frequency of pandemics is expected to increase, as are the number of heavy air pollution days and the incidence of chronic disease, all further exacerbating the impacts of climate change on healthcare systems[6].

Extreme weather events have numerous impacts on individuals, and the frequency and severity of these events is expected to increase with climate change. Extreme heat waves increase rates of heat

stroke, exacerbations of cardiovascular disease[10], faecal-oral transmitted infections[11], and interpersonal violence including domestic violence[12]. Massive wildfires and increased desertification will exacerbate air pollution, which in turn will exacerbate cardiopulmonary diseases[10]. In addition to disrupting sanitation, extreme flooding will increase humidity, providing optimal growing conditions for moulds which will lead to allergically mediated respiratory inflammation[10]. Furthermore, all types of natural disasters have been found to result in symptoms of PTSD and increases in rates of major depressive disorder (even years after the precipitating event)[13].

4. **Does your medical school curriculum address the impact of climate change on the changing patterns of infectious diseases?**

Climate change is expected to change the patterns of infectious diseases in many ways. Vector borne pathogens are expected to broaden their ranges as temperatures increase, although these vectors may even begin to disappear from their traditional regions as these areas become too hot[14]. *Aedes aegypti* – the host for both yellow fever and dengue fever – is an example of a pathogen carrying vector whose territory is expected to expand and then shift, as the changing weather patterns will have uncertain impacts on mosquito breeding grounds. Increased rain with rising temperatures could be favourable for mosquito breeding, but extreme rain and drought will negatively impact their breeding success[14].

Furthermore, extreme temperature and precipitation events have been associated with increased risk of many gastrointestinal and diarrheal illnesses including campylobacteriosis, salmonellosis, shigellosis, norovirus, hepatitis A, cryptosporidiosis, giardiasis, cholera, and those caused by *E. coli*[11, 12, 14]. Extreme flooding specifically has been associated with outbreaks of *Legionella* and non-tuberculosis mycobacteria[11]. Unfortunately, droughts are also expected to lead to increased use of rainwater for drinking water, which combined with the warmer ambient temperatures, could lead to stored water being warm, and thus lead to a much greater risk of exposure to gastrointestinal pathogens, especially in developing regions[11].

5. **Does your medical school curriculum address the respiratory health effects of climate change, including air pollution?**

Heat waves, fires, extreme precipitation, drought, and desertification are expected to decrease air quality and increase levels of particulate matter[10, 14], which is the most damaging element of ambient air pollution to human health[15]. Increased particulate matter levels have also been associated with chronic obstructive pulmonary disease morbidity, and increased risks for morbidity and mortality among individuals with underlying cardiorespiratory illness[15]. Studies in low- and middle-income countries, which often have a greater burden of particulate matter than developed countries, have shown that even short-term exposure to particulate matter is linked to cardiorespiratory mortality[15].

Associations between air pollutants and respiratory problems have been found in several Latin American countries; children are especially at risk of experiencing the harmful effects of air pollutants due to their smaller airways and immature immune defences[16]. Indeed, reductions in levels of air pollutants have been shown to be associated with a decrease in bronchitis, allergic reactions, and asthma in children[16].

Exposure to wildfire smoke has been strongly associated with respiratory morbidity and increased emergency department visits for cardiovascular and cerebrovascular issues[17]. Given the prevalence of such fires will increase, the individuals most likely to be impacted by smoke exposure (i.e. those with pre-existing respiratory diseases, middle-aged and older adults, children, pregnant women and their foetuses, people of colour and those of lower socio-economic status) will all be at even greater risk.

6. **Does your medical school curriculum address the cardiovascular health effects of climate change, including increased heat?**

Cardiovascular health has been investigated thoroughly in relevance to climate change, and it is clear that increased heat levels cause an increase in both mortality and morbidity from cardiovascular disease. For example, in projections for the UK taken as representative of a high-income country, heat-related deaths are expected to rise by 257% by 2050 from those in 2000, assuming the population does not adapt[18]. Heat specifically affects the cardiovascular system in multiple ways, such as via dehydration, and greater ambient temperature, which has the ability to reduce the effectiveness of various cardiovascular drugs[19, 20].

Heat can also exacerbate the conditions of those with pre-existing cardiovascular disease. For example, in one study, 50% of hypertrophic cardiomyopathy (HC) sufferers at one centre saw a deterioration in their HC symptoms due to an increase in ambient temperature[21]. Another study found that hospital admission rates for cardiovascular diseases, ischaemic heart diseases, heart failure and heart rhythm disturbances all increased by over 0.3% for every 1°C increase in temperature variability[22].

Another example of the effect climate change has on cardiovascular health is through the increase in the range of various vector borne diseases, which can become more threatening when paired with existing cardiovascular conditions, or even trigger them in certain cases. For example, Hoffmeister and Aguilar Valdez (2019) investigated adults in Berlin who had been hospitalised by malaria, and found that those with pre-existing hypertension were more likely to develop a severe or life threatening case of malaria. Brainin *et al.* (2021) conducted another study by investigating Danish records and found that of those with no pre-existing cardiovascular conditions, people who contracted malaria had a 30% increased likelihood of developing heart failure in their life. These effects will unfortunately become more prevalent as climate change worsens.

7. **Does your medical school curriculum address the mental health and neuropsychological effects of environmental degradation and climate change?**

Climate change is expected to adversely impact mental health by displacing people from their homelands and by increasing the frequency and extremity of natural disasters and heat waves[5, 6, 12, 25]. Increased migration due to climate change is expected to lead to substantial emotional stress and conflict over food, water, and land resources[5, 12, 25]. Those who are not forced to migrate will likely be impacted by extreme weather events themselves (e.g. hurricanes, typhoons, wildfires and extreme heat waves), which are known to increase the occurrences of interpersonal violence[12], hospitalisation for mental illness and suicide[5], in addition to further decreasing people's connection to the natural environment as they are forced to stay inside[6].

Symptoms of PTSD have been documented following nearly all types of natural disasters[13], and major depressive disorder, OCD and alcohol abuse disorder are more common in individuals affected by natural disasters[13, 25]. However, indigenous communities across the globe are likely bearing the worst of the mental health impacts of climate change[5, 25]; indigenous communities often have strong cultural and identity ties to their environment, and many groups are being actively displaced from their homelands due to climate change, putting them at risk for adverse mental health outcomes[5, 25]. Individuals living in small island nations are reporting difficulty focusing on work and engaging in social interactions due to the stress of having their homes sink under water[25]. Inuit people in Canada are already experiencing displacement and are changing their traditional practices due to climate change[5]. This forced migration has led to reports of financial stress, nutritional stress, changes in cultural identity and even increased substance abuse and suicidal ideation[5].

8. Does your medical school curriculum address the relationships between health, individual patient food and water security, ecosystem health, and climate change?

Increased extreme weather events and prolonged droughts caused by climate change will have major impacts on food production[6]. In fact, food security is one of the main concerns associated with climate change and has major health implications[26]. Studies from subsistence farming populations in sub-Saharan Africa have demonstrated that low crop yields in the year of birth of a child is associated with increased mortality[27]. Furthermore, undernutrition in children is associated with poor health in both childhood and adulthood[26]. While quantitative predictions about the impacts of climate change on food security are difficult to make, it is estimated that an additional 5-170 million people globally will be "at risk of hunger" by 2080 because of climate change[26].

Developed countries, despite having greater resources with which to combat food shortages, will not be immune to the effects of climate change[28]. Food prices are expected to increase globally as food production is impaired by both extreme weather events and the increased use of biofuels – the latter of which is needed to reduce global emissions and will require the displacement of food crops from agricultural land[28]. As food prices increase, consumers choose less expensive food which is often processed and rich in sugars and fats, and begin to steer away from organic produce[28]. This shift towards consumption of high-calorie, low-nutrient diets will likely exacerbate existing health inequalities by increasing obesity rates for children, young adults, smokers, low income groups and the elderly[28]. In addition, shifting food belts may negatively impact the nutritional value of food, as soil composition, growing conditions, harvesting, and processing methods can all impact nutritional qualities, and this would exacerbate the health inequalities described above[28].

In addition to exacerbating food and nutritional deficits, extreme weather events caused by climate change will adversely affect fresh water supplies[29]. Prolonged droughts will decrease water supplies, while extreme precipitation will degrade water resources by introducing pathogens and other contaminants to the water supply during flooding[29]. For example, previous studies have found an association between outbreaks of *Campylobacter* and heavy rain events, especially when the precipitation followed a drought period[29]. In addition, climate change may exacerbate water supply shortages through changing weather patterns, leading to rivers not reaching as far as they did historically[30]. It is worth noting that water scarcity is primarily caused by unsustainable water management[29], however, climate change will exacerbate low ground water supplies, as prolonged droughts will decrease natural recharge rates into aquifers[29].

9. Does your medical school curriculum address the outsized impact of climate change on marginalized populations such as those with low SES, women, communities of colour, children, homeless populations, and older adults?

The projected increase in heat and extreme weather events will have greater impacts on the elderly population, individuals with a lower socioeconomic status, individuals experiencing homelessness, migrants, and indigenous communities[4, 6]. Elderly people specifically are known to have a higher mortality rate for heat-related deaths[3, 6, 7]. Densely populated urban areas with little greenspace (commonly habituated by people with low socioeconomic status and communities of colour) create urban heat islands which exacerbate high temperatures and increase heat-related mortality[4]. Additionally, poor building infrastructure, such as that found in slum dwellings, has been shown to poorly regulate temperature levels, with indoor temperatures commonly exceeding outdoor air temperatures[31]. These disparities in housing qualities then put individuals with low income at even higher risk for heat-related morbidity and mortality.

Unfortunately, because of their location and dependence on the natural environment for their livelihoods, groups such as indigenous populations and subsistence farmers are more likely to be immediately impacted by sea level rise, glacial melt, melting perma-frost and changing weather patterns[2, 5, 27]. Indigenous people may also be at higher risk for experiencing mental health disorders induced by climate change because they often have deep cultural connections to the natural world[5].

10. Does your medical school curriculum address the unequal health impacts of climate change globally?

Climate change will disproportionally impact low- and middle-income countries[2, 32], even though many developing countries have done little to contribute to climate change[32]. Eight of the ten countries most affected by the quantified impacts (fatalities, fatalities per 100,000 inhabitants, absolute loses and loses per unit GDP) of extreme weather in 2019 are categorised as low- or middle-income countries[8]. On top of this, low-income countries have fewer resources to adapt to climate change, and often have larger populations of subsistence farmers[32]. As the climate changes, substantial swathes of land will become uncultivatable and uninhabitable, forcing many of these farmers to become climate refugees[32]. This forced migration will then create increased emotional, financial, and nutritional stress[5], the majority of which will be initially felt by individuals living in low- or middle-income countries.

In addition to being more likely to be impacted by extreme weather events, food insecurity and/or forced migration, individuals living in low- and middle-income countries are also more likely to be exposed to high levels of ambient particulate air pollution compared to individuals living in developed countries, which climate change is expected to exacerbate[15]. The negative health impacts of both short- and long-term exposure to elevated levels of particulate matter are well documented and include increased cardiorespiratory morbidity and mortality. Individuals living in low- and middle-income countries may also be at increased risk of heat-related mortality as poor urban planning and infrastructure can contribute to both increased outdoor (heat islands)[4] and indoor (seen in slum dwellings especially)[31] ambient air temperatures.

11. Does your medical school curriculum address the reproductive health effects of industry-related environmental toxins (e.g. air pollution, pesticides)?

An extensive body of literature has already been produced about the effects of industry-related environmental toxins on many facets of male and female reproductive health[33]. One systematic review analysing 32,789,152 US births found statistically significant correlations between fine particulate matter and ozone and adverse pregnancy outcomes, as well as elevated risk of still birth (though this did not achieve significance). Association was also found between air pollution and both low birth weight and pre-term birth in a majority of studies[34].

A second systematic review analysed the effects of factors related to climate change on female menarche, and found that exposure to lead, polychlorinated biphenyl (a chemical common in industrial waste) and in utero exposure to polybrominated diphenyl ether (a chemical which reduces flammability of products) were associated with a delay in menarche[35]. In addition, different phthalate species (chemicals often used in plastics) were associated with early and late menarche, depending on the species, both of which are themselves associated with a number of adverse effects later in life such as fertility related diseases and foetal loss respectively. Further reviews also found evidence of a positive association between BPA (bisphenol A) and polycystic ovary syndrome[36], as well as evidence that even low exposure to PFAS (per- and polyfluoroalkyl substances) could reduce female fertility and impact developmental steroid hormones. Finally, a meta-analysis also demonstrated a significant increase in maternal hypertensive disorders and increased risk in pre-eclampsia following exposure to air particulates, particularly pronounced during the third trimester[37].

The evidence for effects on male reproductive health is less robust, though many studies have linked pesticide exposure to decrease in semen parameters[38, 39], with some phthalates also associated with decreased semen quality, potentially due to endocrine disruption.

12. Does your medical school curriculum address important human-caused environmental threats that are relevant to the university's surrounding community?

While the geographic range of climate related health emergencies will increase as climate change accelerates, there will still be local and regional differences in the events, health impacts, and preparedness that physicians will need to address, precisely because the impacts of climate change are directly associated with distinct geographic and population vulnerabilities. For example, longer summers and shorter, milder winters allowed the range of disease vectors such as tics (Lyme disease) and mosquitoes (dengue fever, chikungunya, Zika fever and West Nile fever) to increase. Thus, medical professionals in those areas for which this is a new threat must be trained and informed appropriately[40]. Likewise, in arid regions, education on wildfires and lung diseases should be integrated for physicians, due to the greater risk people in that region face[41].

It is also important to consider the resources and needs of a given community, as this directly informs the strategies and options available to combat and adapt to these changes. For example, the Inuit people in Northern Canada have very specific challenges due to climate change, such as increased biting and stinging insects (such as bees, which had never been seen in some regions before), and access to hunting grounds being cut off by melting ice[42]. However, the communities have also been very vocal and articulate about the local impacts, and so possible solutions have been found[43]. Or, more commonly, a city with a large homeless population should have doctors trained in the increased susceptibility of this group to pollution-related illness and the effects of natural disasters. It follows that medical schools would want to educate students on climate health specific to their demographic, to develop a physician workforce that can adequately respond to community needs.

13. To what extent does your medical school emphasize the importance of Indigenous knowledge and value systems as essential components of planetary health solutions?

Indigenous populations worldwide are at a particularly large disadvantage for contending with the health effects of climate change, due to many factors including a historical reliance on natural resources, the centring of community and traditions on the environment, lack of social services, and a history of colonialism that has weakened the autonomy of indigenous communities and their ability for self-determination. However, many of these factors have also contributed to the unique knowledge, skills and culture indigenous communities possess about their local environment, developed through long multigenerational interactions with both the natural world, and each other[44].

These cumulative bodies of knowledge and belief often bring a much greater cultural importance to science, and western science education can be improved and rounded out by increasing the cultural component of science education[45]. It is important to note here that sharing of knowledge must be of mutual benefit, and should not be extractive by nature; knowledge systems should be woven together, to provide a reciprocal exchange of understanding[46]. This is particularly important as many indigenous peoples are understandably very protective of their territories, and thus transgressions or betrayals of trust or understanding can have consequences for future researchers[47].

Beyond the cultural importance of indigenous knowledge, the specific local environmental knowledge indigenous communities can provide, along with the advice they can give for how to act in harmony with nature and be more sustainable, is unparalleled due to their unique experiences. A study by Homann *et al.* (2008) really exemplifies the environmental damage which can occur, when indigenous knowledge isn't utilised in a community. Indigenous knowledge is thus essential to finding planetary health solutions. The unique knowledge of indigenous people can for example contribute to biodiversity conservation[49], impact assessment[50], and natural disaster impact mitigation and response[51]. Most importantly, however, their insight can ensure policies for planetary health solutions are meaningful and applicable at the local level[52].

One method for example with which we are able to monitor climate change is through cultural keystone indicator species, which are species of animals of great cultural importance to indigenous

communities, and whose behaviour or condition can inform us of the local impacts of climate change. However, the subtle changes we can record are only possible due to the expert knowledge of the local communities[53, 54].

14. Does your medical school curriculum address the outsized impact of anthropogenic environmental toxins on marginalized populations such as those with low SES, women, communities of colour, children, homeless populations, and older adults?

In a systematic review of neighbourhood effects on health in Americans, researchers found that Black Americans had the highest mortality rate from exposure to air particulate matter than any other racial group, and other racial minorities were more likely to be exposed to pollution from natural gas[34]. These disparities held across income groups, suggesting the differences aren't solely attributable to socioeconomic status (SES)[55], and it was found in another study that both Black and Latino communities in the US had significantly higher exposure to air pollutants than White people[56]. There is also evidence that Black and Hispanic Americans, as well as those with low SES, are exposed to greater numbers of harmful chemicals such as PCBs (polychlorinated biphenyls), BPA (bisphenol A) and phthalates, which can affect metabolic diseases like type II diabetes (PCBs significantly so)[57].

The 2020 Lancet Countdown on Health and Climate Change summarised that in developing nations, unhealthy and unsustainable energy sources (e.g. indoor fuel burning, for heat, light and cooking) along with coal, predominate. Women and children are disproportionately impacted by this, as they tend to spend more time in poorly ventilated houses doing household chores. The report concluded that 91% of deaths from ambient air pollution occurred in lower- and middle-income countries[58].

Elderly people and homeless individuals in metropolitan areas also have a heightened vulnerability to air pollution, due to greater rates of underlying conditions and an increased time spent outdoors respectively. In one survey of the elderly in the UK, residents described ailments like difficulty breathing and sleeping during periods of increased air pollution, and these periods will only increase with climate change. Poor air quality in particular and even climate change exacerbated heatwaves can also trap older people inside their homes, worsening the problem by cutting them off from health and social care services they may need to cope with these events[59, 60].

15. Does your medical school curriculum address the environmental and health co-benefits of a plant-based diet?

Per-capita emissions from food production are expected to increase by 32% by 2050, resulting in an 80% absolute increase in emissions as the population increases. However, widespread adoption of a Mediterranean, pescatarian or vegetarian diet, could reduce this prediction by 30%, 45% or 55% respectively[61]. Other studies have corroborated this and have also demonstrated that vegan diets can lead to even greater reductions, with conservative estimates showing up to 70% decrease from predictions[62].

Increased meat consumption requires far greater amounts of energy, land and water compared to plant-based diets, and the land use is also inefficient[63]. Consumable animal products account for 83% of farmland use and 80% of global food emissions, but only 37% of caloric intake[64]. Animal trade is also environmentally damaging, as a significant proportion of ecological destruction via deforestation, for example, is attributable to the industry, and intensive livestock agriculture can increase the likelihood of zoonotic disease spillover[65].

Meat rich diets can also contribute to the development of certain health issues, though there are substantial confounding effects in most studies[61]. One study by the Global Burden of Disease found that a diet high in processed meats decreased disability-adjusted life years (DALYs) by 13%, while a diet low in nuts and seeds, fruits, or vegetables decreased DALYs by 40%, 30%, and 12% respectively[66]. Meta-analyses and some studies successful in controlling for behavioural and physiological factors have found that higher total meat, processed meat and/or red meat consumption

can be associated with coronary heart disease, type II diabetes and colorectal cancer[67, 68], to the point where there is reported evidence to classify processed meat as carcinogenic, and red meat as probably carcinogenic, to humans[69].

Broadly, studies promoting plant-based diets more easily demonstrate associations between greater plant consumption and decreased meat consumption with lower incidence of disease. Systematic reviews have found links between vegan diets and decreased cardiovascular risk factors though, as well as significant evidence of short-term benefits on indicators such as weight and inflammatory markers, independent of caloric content. Short-term randomised control studies have been able to demonstrate that a plant-based diet may specifically be beneficial for weight reduction in individuals with obesity, type II diabetes, and cardiovascular disease[70].

16. Does your medical school curriculum address the carbon footprint of healthcare systems?

Healthcare systems worldwide contribute a significant amount to a country's carbon footprint. For example, in 2013, the US healthcare sector contributed approximately 9.8% of the country's total greenhouse gas emissions (GHGe), with significant contributions to air particulate matter levels, persistent organic pollutants, toxic metals, and sulphur and nitrous oxides, either directly from healthcare facilities, or from material production and drug manufacturing in supply chains[62]. These all equated to roughly 470,000 Disability-Adjusted Life Years (DALYs) lost per year, a number comparable to those due to preventable medical errors[71]. Globally, the healthcare sector contributes 4.4% of all GHGe[72], as the healthcare sector in many countries has the largest carbon footprint of any service sector. Indeed, the healthcare carbon footprint for some larger countries is equivalent to the national carbon footprint of smaller nations (e.g. in 2014 the healthcare carbon footprints of China and the US were equal to the national footprints of Canada and Italy respectively)[73]. Within the sector, only 17% of emissions are estimated to be from the operation of healthcare facilities themselves, while 71% of emissions are indirect downstream emissions in supply chains[72]. As such, to adequately address the contribution of healthcare systems on climate change, a comprehensive, system level approach must be used[71].

Infectious waste and the release of unmetabolized, volatile inhaled anaesthetics are of particular concern (see Curriculum metric #17). Outside the operating theatre, solid, non-toxic waste such as from unfinished pre-packaged surgical kits, which leads to the disposal of unused instruments, and single-use personal protective equipment (PPE), are also major sources of emissions[74, 75]. For instance, during the first 6 months of the COVID-19 pandemic, the carbon footprint of PPE distributed to healthcare and social services in the UK was estimated to be 26,662 times the global average person's in a non-pandemic time period[75].

Barna *et al.* (2020) writes that upholding the principle of "do no harm" requires that we must balance the care of individual patients with concern for the care of the environment and community; educating current medical and health professional students about sustainability in the healthcare system is a key factor in improving the sustainability of the healthcare system[77].

17. Does your medical school curriculum cover these components of sustainable clinical practice in the <u>core</u> curriculum? (1 point each)

a. Waste production within the healthcare system and strategies for reducing waste in clinical activities, such as in the operating room.

Reduction of waste and wastefulness represents one of the largest possible improvements to sustainability and reductions in emissions within a hospital[78]. There are many varied sources of waste however, from plastics, pharmaceuticals and medical waste, to unnecessary journeys and procedures.

For physical waste, it is important to consider waste both in and out of the hospital. While it is possible to manage what occurs to different types of waste within a hospital to a degree, alternative strategies need to be employed to encourage proper disposal, and reduction of waste, for prescribed pharmaceuticals outside the hospital. This proportion of waste is critical; one study in Vienna determined that the majority of disposed medicines are prescription only, and thus a responsibility of the hospital, and that 95% of the disposed medications hadn't even expired when disposed of[79].

In the wake of COVID-19, medical waste is even more of an issue, especially due to the rapid increase of personal protective equipment (PPE) issuance[80]. Much of this PPE is frequently disposed of in ways detrimental to the environment, such as incineration (or landfill for excess non-hazardous waste), and the increased quantity makes this particularly dangerous. During the first 6 months of COVID-19, 1.8 billion extra items of PPE were issued in the UK alone, equivalent to 107,000 extra tonnes of CO_2[75].

Pre-COVID, operating rooms were the largest sources of waste in hospitals, at 70% of all waste[81, 82]. Of this, as much as 90% of infectious waste, which needs to be incinerated and cannot be sorted for reuse, currently is misallocated, and thus imparts a disproportionate environmental and financial cost to dispose of[82]. In fact, one centre implemented changes such as reusing surgical scrubs and jackets, as well as limiting the use of infectious waste bags to only when patients are in the room, and managed to reduce medical waste volume by 50% over 7 years[83].

b. The impact of inhalers on the healthcare carbon footprint and the environmental benefit of dry powdered inhalers over metered dose inhalers.

Wasted medication is a large drain on medical services, while simultaneously being detrimental to the environment; in the NHS in the UK, this amounts to £300 million a year as estimated by Trueman *et al.* (2010), and the plastic and chemical fluids discarded contribute to water pollution if not handled properly. Inhalers are a particular instance of this, as they are prescribed in large numbers (~160 million in the US in 2020[85]), and many are unaware that they can be recycled (around 57% of users in one UK study[86]). Metered dose inhalers make up around 8% of the NHS carbon footprint due to their casings, and the doses remaining upon disposal which contain hydrofluorocarbons (HFCs), which are potent greenhouse gases[87]. In one study investigating waste, which collected 481 inhalers, the equivalent of 2.63 tonnes of CO_2 remained unreleased in unused doses; of those that had counters (201), 8546 unused doses were counted[88]. In order to minimise the emissions from inhalers, dry powder inhalers can be used over metered dose inhalers containing HFCs, as these contribute the equivalent of 422kg CO_2 less per patient per year[89].

c. The impact of anaesthetic gases on the healthcare carbon footprint and ways to reduce anaesthesia environmental impacts, such as total intravenous anaesthesia or choosing less environmentally anaesthetic gas options with reduced greenhouse gas emissions.

The release of unmetabolized, volatile inhaled anaesthetics is a particular concern of waste from the operating room, with nitrous oxide and desflurane being particularly worrying. Nitrous oxide is minimally metabolised in humans (approximately 0.004%[90]) and both gases have especially high life-cycle greenhouse gas effects[91], with one study finding that 6% desflurane for one day of surgery (flow rate 0.5 L/min) equated to driving roughly 4000km in a car[91]. In the UK, anaesthetic gases account for 2% of the carbon footprint of the NHS[92], due to their atmospheric lifetime and potency[91]. Isoflurane and sevoflurane are less harmful, remaining in the atmosphere for under 6 years[93] and having 510 and 130 times the warming effect of CO_2 respectively[94]. In comparison, nitrous oxide has 300 times the warming potential of CO_2[94] and lasts for over a century[95], and desflurane lasts for 21 years[93] and can cause over 2500 times the warming of CO_2[94]. Both nitrous oxide and desflurane are also ozone depleting substances[93], with nitrous oxide depleting more total ozone than any other gas in our atmosphere[96].

A few strategies to minimise the environmental impact of anaesthetic use have been created. Firstly, reducing the flow rate of gases, with the close monitoring of an anaesthetist, can provide sufficient anaesthesia while minimising released gases, with reductions of up to 75% in some studies[97]. Better machines can also help to monitor and keep the total volume of gas to a minimum while ensuring safety, and even older machines can be fitted with gas sequestering and capture systems[98]. This is in addition to replacing gaseous anaesthetics with total intravenous anaesthetic (TIVA), which minimises inhalation agents the most; the life cycle assessment of emissions for using TIVA is in fact four orders of magnitude smaller than using desflurane, which is a phenomenal reduction[94, 99].

d. The environmental impact of pharmaceuticals and over-prescribing as a cause of climate health harm. Alternatively teaching on deprescribing where possible and its environmental and health co-benefits would fulfil this metric.

e. The health and environmental co-benefits of non-pharmaceutical management of conditions where appropriate such as exercise or yoga classes for type 2 diabetes; social group activities such as gardening for mental health conditions; active transport such as bicycle schemes for obesity. This is commonly known as social prescribing in the UK.

In the UK, it is estimated that 10% of items dispensed in primary care are inappropriate[100]. When taking into account over-the-counter medication, such as the tens of millions of women taking oral contraceptives globally[101], the number of pharmaceutical products disposed of, possibly through improper means, is staggering. The UK government has acknowledged this, and published the "Good for you, good for us, good for everybody" plan in September 2021 to both reduce overprescribing and increase social prescribing[100].

The disposal of medication leads to a non-negligible amount of many different pharmaceuticals in a wide range of biomes, in soils, surface waters and ground waters[102]. While there are few acute effects as a result of this, longer term effects from the accumulation of these chemicals in ecosystems have been reported, such as changes in behaviour and fertility in fish[103]. For some gaseous medication such as anaesthetics, the chemicals themselves have direct negative effects on the climate as well, not just on ecosystems (see Curriculum metric #17c).

In order to reduce the quantity of disposed medication, non-pharmaceutical interventions can sometimes be prescribed instead, and this is known as social prescribing. This aims to give people time and opportunity for discussions focussed on their needs and wants, in order to address issues caused by their affliction in their life, rather than treating symptoms with medication[104]. Social prescribing has been evaluated multiple times, and despite the difficulty in measuring its effectiveness due to its heterogeneity[105], it has been linked with better outcomes for patients[104]. For example, Wildman *et al.* (2019) demonstrates that patients with long term conditions when paired with link workers as part of social prescribing, can improve their adherence to programmes, and report feeling better about their healthcare.

f. The health and environmental co-benefits of avoiding over-medicalisation, over-investigation and/or over-treatment.

Over-medicalisation describes medical practice which is not validated. Over-treatment and over-investigation are terms used to describe parts of this, and describe medical practice which is not necessarily inappropriate, but when the medication or testing is unlikely to cause a net material benefit to the patient, be that due to high risks, or low efficacy paired with adverse effects[107]. By Curriculum metrics #17d and #17e above, over-treatment has many environmental issues, namely unnecessary chemical and plastic waste generation similar to over-prescribing, but it cannot be solved as easily. Over-investigation is similarly complicated to address, but by reducing unnecessary scans and tests in healthcare centres, we can reduce energy use[108], leave people happier and mentally healthier[109], and save money (roughly $200 billion is wasted a year in the US on unnecessary testing)[110].

18. **In training for patient encounters, does your medical school's curriculum introduce strategies to have conversations with patients about the health effects of climate change?**
19. **In training for patient encounters, does your medical school's curriculum introduce strategies for taking an environmental history or exposure history?**

The way in which physicians interact with patients is key to patient outcomes, in terms of knowledge, attitudes and behavioural changes. Health professionals are regarded as trusted sources of information by patients[111], which puts them in a unique position to counter misinformation about and otherwise address controversial topics, such as climate change and the danger of environmental exposures. This is important as the most cited reason physicians give for not having these conversations currently is a lack of knowledge on how to discuss these topics with patients[112]. In addition, from a patient's perspective, having good relationships with caring and informed doctors remains one of the most important factors in medical decision making, hence the importance of practicing and developing skills to build these relationships[113]. For example, a warm rapport with paediatricians is the number one reason parents decided to vaccinate their children based on a US survey[114]. Separate studies have specifically shown the benefit of different kinds of patient interactions, such as physically handing patients credible and clear materials[115], and framing suggestions about climate action with the emphasis on the benefit to the patient and their priorities[116].

Due to certain exposure risks being less controversial than others, such as the link between outdoor air pollution and asthma, there is a decreased need to inspire confidence in patients when discussing some environmental exposures, however, it is still critical for healthcare professionals to take environmental histories when talking to patients to diagnose environmental health problems[117]. It is also the case that many exposure risks are less well known by the public, and indeed by healthcare professionals, such as the risk of lung cancer from indoor radon gas[118]. This means the points above about establishing rapport are very much applicable to environmental exposure risks as well.

20. **Is your medical school currently in the process of improving Education for Sustainable Healthcare (ESH)/planetary health education?**

The omission of climate change education from many medical training programs worldwide, despite the dire and imminent consequences to public health, demands urgent attention[1, 2]. The International Federation of Medical Students Association called upon medical schools to incorporate climate and health education by 2020[119] as a result. Schwerdtle *et al.* (2020) offer additional support for this, arguing that education for sustainable healthcare (ESH) should have already progressed past the point of merely acknowledging its relevance to health professions. Instead, medical institutions should now be focused on actively implementing ESH. However, in a series of three surveys administered to 2,817 medical students in 112 countries between March 2019 and March 2020, only 15% of respondents reported receiving formal climate change education through their institutions[121]. ESH and planetary health education aim to teach medical trainees a deep understanding of links between the environment and human health, knowledge and skills needed to handle the increased disease burden caused by climate change, and a commitment to sustainable healthcare advocacy and action[76, 122]. Active improvements in sustainable healthcare and planetary health education are therefore recommended.

21. **How well are the aforementioned planetary health/Education for Sustainable Healthcare topics integrated longitudinally into the core curriculum?**

There is a consensus among experts in planetary health fields that education for sustainable healthcare (ESH) should be longitudinally implemented into medical curricula. A survey of 52 experts on Sustainable Healthcare Education (SHE), which applies planetary health principles to medical curricula, showed the vast majority of respondents believed SHE principles should be taught throughout pre-clinical and clinical years of medical school[123]. Similarly, SHE experts in the UK recommended embedding education about sustainability as a running theme throughout medical education, rather than as a singular topic, in order to promote student-educator collaboration and

enhance learning about healthcare sustainability[124]. Furthermore, introducing climate change early in medical curricula and integrating it throughout the stages of medical education highlights its importance and helps students relate it to their growing professional identity[125]. This may ultimately help students develop the self-awareness and intrinsic motivation necessary to combat planetary health issues beyond medical school[120]. These findings and perspectives support longitudinal integration of sustainable healthcare and planetary health education into medical curricula.

22. **Does your medical school employ a member of faculty to specifically oversee and take responsibility for the incorporation of planetary health and sustainable healthcare as a theme throughout the course?**

Medical schools often employ many different lecturers all from many different disciplines. Thus, the level of coordination needed to incorporate planetary health and sustainable healthcare throughout a medical curriculum would be monumental. Team leaders are essential for meeting project goals, especially when coordinating with different groups of people[126], and so at the minimum a dedicated member of staff would be required to lead the effort, to ensure success in a timely manner[127].

Interdisciplinary Research

1. **Are there researchers engaged in planetary health research and healthcare sustainability research at your medical school?**

The current focus of the majority of medical research by physicians is on advancing complex medical technologies and techniques, and while this is undoubtedly a valuable pursuit, research on preventative measures and environmental contributions to health often go under-investigated. At the same time, the vast majority of healthcare expenditure in developed nations is on the treatment of chronic diseases, such as the US, where 90% of annual costs are due to chronic conditions or mental illness[128]. These illnesses are often inextricably linked with our environment, through factors such as air quality, food and water systems and population density. This is then only exacerbated by the fact many healthcare institutions are largely unsustainable, thus contributing to climate change[129].

Education based in these areas and focusing on aspects of medicine which will become more relevant as the climate changes, such as natural disasters and zoonotic diseases, is imperative. Physicians should be capable, not only in the face of the impact of natural disasters on individuals (such as the mental health consequences and complicating factors such as hunger), but when delivering care without certain hospital infrastructure, in the event hospitals or machinery are damaged[130]. Large scale infectious diseases, such as COVID-19, are also expected to become more prevalent, and without substantial research even after this pandemic is under control, the possibility of being as woefully underprepared for a second would be very real[131].

Climate scientists have developed detailed models regarding the changes ecosystems and weather patterns will undergo in the coming years, but projections regarding health risks and research into evidence based policies to combat those risks are lacking[130]. This is partly due to a propensity to consider climate change as an environmental problem rather than a health problem, despite the fact more health organisations have begun to express concerns on the health impacts of climate change[132]. Physicians have a responsibility to lead the way to a better understanding and preparedness of human health in a changing climate.

2. **Is there a dedicated department or institute for interdisciplinary planetary health research at your institution?**

The field of planetary health is necessarily interdisciplinary, as it has emerged to address the mosaic of challenges posed by a changing climate. It has emerged in response to the unprecedented and accelerating ecological devastation that threatens the health of humanity[133]. Since the field of planetary health recognises that human health is at the intersection of both man-made and biological spheres, we need experts from multiple disciplines to come together to produce research on it. While it is apparent why this necessitates researcher collaboration, there are multiple ways in which to broaden the scope of planetary health. For example, to successfully mitigate climate change, collaboration between different peoples and governments is essential. Therefore, planetary health research could include studies to understand what helps or hinders human cooperation, which would require knowledge from sociology and the humanities to communications and media. Furthermore, policy change is crucial for our response to climate change, so political scientists could be brought in to collaborate with researchers from fields like biology and atmospheric chemistry to come up with effective policy solutions[134]. A paper on the facilitation of innovation in medicine and healthcare states that collision of ideas is critical to fostering innovation – "Co-location, gathering spaces, and more formally, interdisciplinary institutes become strategies to enable fortuitous, chance encounters that can lead to unconventional collaborations. These, in turn, can yield transformative results."[135] Unfortunately, there are some particular barriers to interdisciplinary research institutes. One particular study found that research proposals spanning more diverse disciplines had lower funding success rates; this can lead to negative feedback cycles in which interdisciplinary research is viewed as higher risk, and thus less popular among researchers. It also takes significant time to build the collaborative relationships necessary for quality interdisciplinary research, as well as cultivate experienced researchers who can develop a common language and framework between multiple disciplines[136].

3. **Is there a process by which communities disproportionately impacted by climate change and environmental injustice give input or make decisions about the research agenda at your medical school?**

In order to properly approach climate policy and research, academic departments need to collaborate with more than just each other, but with governments, community organisations and stakeholders who will be affected by climate change. Not only does involving the public and those with invested interest foster a greater sense of trust in science and give those enacting a policy or idea a sense of accountability, but their views are critical to the creation of effective policies in the first place. Many outcomes and recommendations from research will need to be implemented in communities, and therefore an understanding of their cultural norms is essential for successful implementation[137].

Members of marginalised communities, indigenous people for instance, can also offer unique perspectives and solutions for how to act most sustainably, which may otherwise go unnoticed by academia. The traditions of many indigenous peoples are consistent with the idea of planetary health, as they are rooted in a recognition of the interconnectedness of humans and all living things, and the impact of disrupting any part of the environment on the health of all its inhabitants[138].

One example of effective collaboration is that of the highly remote Inuit community in Nunatsiavut, Canada. This community, who rely on traditional hunting methods, are understandably concerned about the effects of climate change on ice break-up, harsher weather, and declining food and water systems. The community government partnered with a team of researchers, who conducted interviews to examine the effects on the community. They also helped facilitate a digital storytelling project, designed by members of the community and in coherence with the important tradition of oral story telling in their culture. The team was able to gather a picture of the community beyond only

quantitative data and identified digital storytelling as a potential strategy for raising awareness in future[139].

4. **Does your institution have a planetary health website that centralizes ongoing and past research related to health and the environment?**

Despite planetary health requiring collaboration between many diverse actors, research is primarily conducted in discrete academic departments at the moment, many outside the biomedical sciences[130]. This lack of centralised information makes it difficult for students to learn about and become involved in planetary health research, in addition to other barriers for youth engagement and activism in place today. Those who do make meaningful progress, such as the indigenous Pacific Islander activists who advocated for climate action on behalf of their communities at the 2017 UN Climate talks, often have their efforts go under-recognised[140, 141]. In order to recognise this, medical schools should have a space for communication with students about sustainability efforts and research, as medical students are some of the biggest advocators for planetary health. This could also increase transparency and promote opportunities to students for involvement as well[141].

A website also allows for better dissemination of information, which as significant and trusted influencers in their respective communities, universities would benefit from. While many medical schools are housed in a larger institution that is likely to disseminate sustainability information through a website of their own, it would be beneficial to have a specific site or page related to the effects of climate on health, which could more directly affect the lives of students and the local community. One such example is the Climate MD project run out of The Centre for Climate, Health, and the Global Environment at Harvard T.H. Chan School of Public Health. This site contains training resources for current and future physicians on the effects of climate change on health, as well as information for patients, and is a good example of a physician-led program that improves accessibility of climate health information[142].

5. **Has your institution recently hosted a conference or symposium on topics related to planetary health?**

In 2019, medical students at Emory University worked with their faculty to organise an interdisciplinary panel on climate and health at the School of Medicine. This event fostered support for planetary health education in the curriculum and engendered discussion and ideas about how to develop it. Medical school conferences on planetary health in general can facilitate similar connections between students, educators, researchers, and community stakeholders[143]. Conferences also have the benefit of highlighting specific regional or local concerns and solutions, specifically climate health effects in this case, and transdisciplinary connections, both of which are essential in planetary health education[2, 130].

This suggests that to participate in a medical conference at one's own institution has the potential to generate a level of awareness and involvement that may not develop from only a generalised national/international curriculum, as regional differences in climate, population and climate effects will necessarily create demands on doctors not readily generalisable[2]. This means that it's important that medical students in particular can meet experts in the region that they one day hope to serve. Research has also described the need for deliberate space creation to foster innovation in health education[144] and opportunities for innovators to interact and share ideas, such as diverse medical conferences[135].

6. **Is your medical school a member of a national or international planetary health or ESH organization?**

Due to the substantial need for collaboration in addressing the evidence of the deleterious effects of climate change on human health, a number of transdisciplinary coalitions have been developed by global health institutions. These were formed with the intention that membership of medical schools (or other organisations) could provide opportunities for cooperation, and signal the commitment of a member to the problem[133].

One such initiative is The Planetary Health Alliance, co-housed between Harvard T.H. Chan School of Public Health and the Harvard University Center for the Environment. It aims to promote transdisciplinary approaches to improving planetary health, including educating and training healthcare practitioners in planetary health, public outreach, and policy engagement in the public and private sectors. In 2018, the 200 member institutions (NGOs, universities, research institutes, professional associations) collaborated to create a set of 12 core values, designed to be broadly applicable to educators of all nationalities, teaching at any level, to promote a framework for planetary health education[145].

The Global Consortium on Climate and Health Education (GCCHE) is another example of a collaborative effort, this time between the Columbia University Mailman School of Public Health and the United States White House, which aims to bridge current gaps in knowledge and provide educational programs on the adverse health effects of climate change. Its goal is to ensure that all types of healthcare providers across the world have the tools and resources necessary to respond to the impacts their patients will face due to climate change. Each member institution (of roughly 115) appoints a representative to participate in conversation with other schools to develop planetary health curricula and standards with support from GCCHE resources[146].

Community Outreach and Advocacy

1. **Does your medical school partner with community organizations to promote planetary and environmental health?**

Silberberg and Martinez-Bianchi (2019) synthesised literature on community-engaged health studies and produced a list of evidenced benefits, including enhanced dissemination of research, enhanced outcomes, increased likelihood results will be used, and improved trust between researchers and communities, which creates opportunities for future collaborations. Most importantly, properly designed community-engaged research studies can improve health behaviours and outcomes[147, 148]. In recent years, academic medical centres have increasingly realised the need to address community health, as a result of the growing body of evidence showing that social determinants of health are a greater predictor of health outcomes than biomedical determinants, and the fact that while the threat of climate change is global, its effects will differ locally.

The United States National Academy of Medicine cited community engagement as a core competency in the education of health professionals[149]. The Lancet Commission on Education of Health Professionals for the 21st century also recommended that academic institutions create strong community relationships to emphasise community engagement as a core value[150]. In a survey of population health-focused departments in US medical schools, all 9 engaged in community partnership and verbalised the value of working with their local community to plan and prioritise research. This study identified medical education as a critical component in advancing population health in academic medicine, as a field creating innovative strategies for improving health equity[151]. One example of this type of partnership comes from a study conducted by epidemiology researchers from Columbia University and the New York City non-profit WE ACT, which uses community-based action to promote public and environmental health initiatives. Supervised by researchers, youth

interns from WE ACT placed air quality monitors around the city, to see if certain areas were disproportionately impacted by pollution. The researchers identified the advice from the non-profit and youth interns as key in study design and implementation, and WE ACT was able to use the results of this research to advocate on behalf of their community to city policy makers[152].

2. **Does your medical school offer community-facing courses or events regarding planetary health?**

It is rare for courses to be open to the public regarding medical issues that do not directly concern them, thus there is a lack of research in this area. However, it has been shown that courses in secondary schools can be extremely beneficial for reducing the incidence of certain behaviours such as overeating and thus obesity, or for the prevention of sexually transmitted infections[153]. It has also been shown that health literacy, the understanding of the public about the various risk factors and their consequences regarding their health, is a critical component of preventive medicine – mostly because the patient themselves is the most important determinant of their own health[154]. Their decisions are the most important factor, and improving health literacy can help reduce health inequalities as well[155].

Whilst it is unclear what the best way to approach improving patient health literacy is, web-based education courses have been shown to be effective[156]. As Nutbeam *et al.* (2017) found, we are at the beginning of much research into this strategy, though not many best practices have been surmised as of yet. Nevertheless, health literacy will not be improved by providing no information to communities regarding health issues or risk factors they may face.

3. **Does your medical school have regular coverage of issues related to planetary health and/or sustainable healthcare in university update communications?**
4. **Does the institution or main affiliated hospital trust engage in professional education activities targeting individuals' post-graduation with the aim of ensuring their knowledge and skills in planetary health and sustainable healthcare remain up to date during their professional career?**

The need for both current and future physicians to be educated about climate change and its impact on human health is widely accepted amongst health experts. The American College of Physicians (ACP) believes physicians and others in the healthcare community can serve as advocates for health policy change, educators for their patients and communities, and examples of how to implement sustainability practices in daily life[112]. One policy recommendation put forth by the ACP includes incorporating climate change topics into continuing medical education (CME). Valois *et al.* (2016) offer support for this idea, showing that a 3-hour CME would help family physicians integrate climate change knowledge into their daily practice. Another tool for educating healthcare students and workers is via university update communications, such as emails or newsletters. Regular coverage of planetary health topics in university communications would help integrate sustainability education across the entire medical curriculum and emphasise the importance of interprofessional collaboration in addressing climate change, which are important aspects of a successful planetary health curriculum[120, 124].

5. **Do hospitals affiliated with your medical school have accessible educational materials for patients about environmental health exposures?**
6. **Do hospitals affiliated with your medical school have accessible educational materials for patients about climate change and health impacts?**

There is very little research on the specific effect of educational materials in hospitals, either physical materials such as leaflets and posters, or links to virtual materials such as QR codes with webpages. The research that does exist is quite conflicting and is mostly centred on preventative medicine or behavioural changes such as healthy eating or smoking. However, findings can still arguably be

applied to other types of preventative lifestyle changes, such as those to combat climate change or limit environmental exposures.

Some studies suggest that certain types of materials have varying levels of effect, such as the study by Hasanica *et al.* (2020) that indicated that leaflets have no statistically significant effect in the hospital on increasing patient knowledge, but that posters are able to moderately increase patient knowledge and attitudes in the long term. For medical professionals, brochures are able to increase knowledge of primary care physicians according to Bester *et al.* (2016). Other studies however, such as that by Grudniewicz *et al.* (2015), claim that printed educational materials have no effect on patients or doctors (measured by their knowledge and patient outcomes).

Despite this, it has been shown separately that patient education has real benefits in terms of health outcomes and health equity by Hahn and Truman (2015). It has also been shown that those in the UK for example are supportive of a move by the NHS to a more preventative model[162]. Together, it would seem that people aren't so much opposed to learning about things that affect their health, but that methods of delivery are poor. Some of the studies mentioned above did conclude that better ideas for patient communication and educational materials are needed[158, 160], and there has been some success with using timely digital information[163], but this has not been tested for preventative medicine yet. Overall, educational materials seem integral to developing a more efficient healthcare system, though more research is required to determine best practices.

Support for Student-Led Planetary Health Initiatives

1. **Does your institution offer support for medical students interested in enacting a sustainability initiative/QI project?**
2. **Does your institution offer opportunities for medical students to do research related to planetary health and/or sustainable healthcare?**
3. **Does the medical school have a webpage where medical students can find specific information related to planetary health and/or sustainable healthcare activities and mentors within the medical school? For example, projects achieved, current initiatives underway at the medical school and/or contact of information of potential mentors.**
4. **Does your medical school have funded, registered student groups dedicated towards fostering a culture of planetary health engagement, scholarship, and advocacy on campus, supported by faculty advisors?**
5. **Is there a student liaison representing sustainability interests who serves on a medical school or institutional decision-making council to advocate for sustainability best practices?**
6. **In the past year, has the institution had one or more co-curricular planetary health programs or initiatives in the following categories?**

Training future physicians to become devoted advocates of planetary health and sustainable healthcare requires non-traditional approaches to medical education. Planetary health education must first of all be humanistic and learner-centred[125]; encouraging the development of self-awareness and the pursuit of intrinsic motivations may be what helps medical students actualise the life-long dedication required to mitigate climate change. Transdisciplinary and interprofessional problem solving are also necessary elements of a planetary health curriculum[120]. Transdisciplinary approaches integrate natural, social and health sciences, while interprofessional problem solving promotes student-educator collaboration, which can help enhance sustainable healthcare learning[124].

Furthermore, it has been demonstrated that there is a positive correlation between co-curricular activities at university and self-efficacy in students, i.e. that those who engage with a greater number of activities have a greater impact in the world[164], and a further study concluded that a variety of co-curricular activities are beneficial to students' development[165]. It is for these reasons that these types

of activities are recommended to produce effective advocates after university; it is not enough to only teach students the facts about climate change – an emotional impact is important as well[166].

As an example of the types of activities that may be effective and relevant beyond the curriculum, the Health and Environmental Adaptive Response Taskforce (HEART) of the Canadian Federation of Medical Students encourages activities such as students conducting quality improvement projects related to sustainability in hospitals, and interviewing physicians about their clinical experiences in successfully implementing green healthcare initiatives[167]. HEART puts emphasis on the key role of students in climate change advocacy and encourages interprofessional collaboration. Their work has helped garner additional support for planetary health initiatives from physicians nationwide[119], underscoring the importance of supporting and collaborating with medical students, and providing co-curricular enrichment opportunities.

Campus Sustainability

1. **Does your medical school and/or institution have an Office of Sustainability?**

Given the substantial impacts that climate change, biodiversity loss and increased air pollution will have on human health[1], medical schools have a responsibility to address the ways in which their institutions are contributing to these crises, and to provide education about associated hazards and mitigation strategies[168]. The Australian Government Department of the Environment and Heritage has made 13 recommendations centred around policy, practice, and research for universities to follow when attempting to "green" their campuses[169]. They also recognise that the greatest challenge to accomplishing these recommendations will be forming a well-coordinated institutional approach[169]. Given the scope and complexity of addressing and mitigating climate change on university campuses, appointing a designated team with clear leadership seems like the only feasible solution. Having a designated Office of Sustainability on campus would provide a formal team which could be equipped to take on the challenges posed by preparing for a warmer planet.

2. **How ambitious is your medical school/institution's plan to reduce its own carbon footprint?**

At present, we are forecast to reach an approximate 3°C rise in temperature above pre-industrial levels by the end of the century, if we consider a 'continuing climate action' model[170]. Thus, we need to act quickly and decisively, with carbon emissions at net zero by 2050, if we are to achieve our target of only a 1.5°C rise in global temperature as set out by the 2015 Paris Agreement[171]. Failure to accomplish this will result in a significant, negative effect on human health[172], for example via increased heatwaves and fires[173], greater prevalence and transmission of certain diseases like Lyme disease and vibriosis[174], and more hazardous working conditions for physical labour in hot regions[175].

Having adequate plans to achieve carbon neutrality by a certain time is also key to actually realising it, as the ability to measure progress towards sustainability goals helps us achieve them[176].

3. **Do buildings/infrastructure used by the medical school for teaching (not including the hospital) utilize renewable energy?**

The energy demand in the education sector makes up approximately 13% of all total energy use[177], and in the higher education sector, specifically in medicine and other research-heavy scientific disciplines, the proportion is especially high[177]. Broadly, that energy will be provided either by fossil fuels or by renewable sources, however, there are many reasons as to why medical schools should be supplied by renewable energy over fossil fuel combustion. Indeed, this need to transition from

monotonic fossil fuel dependency to renewable alternatives is acknowledged in the UN's seventh sustainable development goal[178].

If we use even 1/5 of all our fossil fuel reserves, we would produce enough greenhouse gas emissions (GHGe) to surpass the limit of 2°C rise in global temperature agreed in the 2015 Paris Agreement[179, 180]. Around 2/3 of global GHGe are due to fossil fuel energy supply and use[181], and it has been found that renewable energy utilisation and efficiency measures could potentially achieve 94% of the required reduction in GHGe by 2050[182]. Thus, investment in renewable energy utilisation, research and development are essential to ensuring a future with minimal fossil fuel use[183].

As renewable energy is more environmentally friendly compared to fossil fuels[184], there are also substantial health benefits to increasing renewable energy utilisation. With an increase to 36% renewables in global energy consumption by 2030, there could be up to $230 billion annual avoided health costs[185]. Moreover, there could be significant financial benefits as well, with for example increased energy security[186], on top of a potential 11.6 million additional indirect and direct jobs in the global energy sector (accounting for job losses from the fossil fuel sector)[187].

While absolute numbers vary for how much impact a global transition to renewable energy would have, there is consensus that renewable energy will play a vital role in the decarbonisation of the economy.

4. **Are sustainable building practices utilized for new and old buildings on the medical school campus, with design and construction of new buildings and remodelling of old buildings conforming to a published rating system or sustainable building code/guideline?**

Professionals responsible for the development of the built environment have the opportunity to implement mitigation measures, which benefit both the natural environment and the health of the public[188]. Currently, 40% of the total energy consumed in the US and Europe is associated with residential and commercial buildings[189, 190], much of which is due to existing buildings, and not the development of new ones. Thus, the improvement of the environmental profile of existing buildings, via retrofitting for instance, is essential to reducing the environmental impact of the building sector[191]. Preventing heat loss for example through improved insulation, which accounts for an estimated 60% of energy use, can have massive effects. Heat loss from windows can also be minimised, for instance by switching to near-infrared electrochromic windows from conventional windows, which can prevent up to 50% of energy loss[192].

With regards to the design and construction of new buildings, it is estimated that GBCC (green building code and certification) compliant buildings have an average of 14% fewer life-cycle environmental impacts compared to non-compliant buildings[189]. However, this can change widely depending on the GBCC system used. Ultimately, however, there are many opportunities to minimise the environmental impact of a new building: advanced planning of a building's envelope can help reduce heating and cooling loads by 40%[193]; use of heat recovery systems allows the recovery of about 60-95% of wasted energy[193]; and use of rainwater harvesting systems can reduce storm water runoff and potable water demand by about 60-80%[194, 195].

Research has also shown that global energy savings in the building sector from energy efficiency, fuel switching, and renewable measures could result in approximately 84 gigatonnes of CO_2 being saved by 2050[196].

5. **Has the medical school implemented strategies to encourage and provide environmentally friendly transportation options for students and reduce the environmental impact of commuting?**

The rapid and mass transport of people on a day to day basis is one of the foremost concerns when considering contributions to climate change and health, not only due to the emissions, particulates and noise pollution produced per driver, but the fact effective transport incentives have been shown to improve physical activity and facilitate social interactions[197]. Lack of physical activity is associated with 1,000,000 deaths per year in the World Health Organization (WHO) European region[198], which could be decreased through encouragement of more active travel, as encouraging and providing infrastructure for cycling for instance can increase physical activity in the community, by effectively raising the proportion of cyclists[199].

As a medical school there is an obvious limit to the extent at which environmentally friendly transportation can be encouraged and supported, however, some of the interventions most encouraged by the WHO are in fact feasible for non-governmental institutions to implement as well[197]. Using cycling as an example again, it is a relatively easy option of travel to encourage besides walking, and for short commutes it is one of the most efficient ways to travel, producing up to 12 times fewer emissions per km than if a person used a car[200].

Medical schools can impact their communities in more involved ways as well, such as increasing the proportion of electric vehicles owned by the university for larger scale student transit[201], or by simply providing economic incentives which encourage public transit use[202, 203], which have also been shown to improve health outcomes[199]. Simulated models have suggested that these initiatives, especially implementing more than one of them, can have significant impacts on bus use for example, and on the amount of active transport of a person[197].

6. **Does your medical school have an organics recycling program (compost) and a conventional recycling program (aluminium/paper/plastic/glass)?**

The ease with which goods can be bought and discarded has led to a linear approach in human consumption, which drains natural resources and harms ecosystems across the world[204]. Improving waste management with better recycling and composting programs is thus vital to transitioning to a more environmentally friendly circular economy[205].

Recycling has many clear benefits beyond reducing virgin material use. For example, producing plastics via recycling rather than with virgin plastics has a 70% reduction in energy use[206], and it is estimated that in 2015 in the US, reclamation of materials such as paper, wood and metals managed to divert 186 million metric tonnes of CO_2 from landfill[207]. Recycling also avoids the direct impacts that can occur due to waste production; for example, recycling plastic can reduce the amount of microplastic detritus in water systems which has been found to be detrimental to both human and animal health[208]. Compostable material on the other hand represents a sizable proportion of an average city's waste, often over 50%[209], and as such food currently accounts for the largest percentage of landfill space[210]. In landfill, organic waste also produces greenhouse gas emissions in the form of CO_2 and methane, and food wasted just by consumers and retail accounts for just over 2% of all global emissions[211]. If composted, these emissions could be reduced, as methane is not created in most composters and carbon emissions can be reduced by 50%[212].

The main alternative to either landfill or recycling is incineration. However, incinerators are also detrimental to public health, as they can increase the risk of developing recurrent respiratory symptoms[213], as well as certain cancers such as Non-Hodgkin's lymphoma, in the areas surrounding

them[213, 214]. Recycling is thus a safer method of waste management, and given that recycling can create more jobs than either incineration or landfill, recycling can be the most economically beneficial as well (recycling creates 115 jobs compared to 2 jobs for incineration and landfill respectively to deal with 10,000 tons of waste)[215].

The success of any recycling or composting program is dependent on consumer involvement and adherence. Factors such as consumer awareness[216], perceived efficacy[217, 218], and convenience[219] are vital to achieving high participation rates, and thus, tailoring programs to consumers is essential[220]. Indeed, results from one study suggest satisfaction with waste management should be measured and taken into consideration in order to improve adherence[218].

7. **Does the medical school apply sustainability criteria when making decisions about the campus food and beverage selections (e.g. local sourcing, reduced meat, decreased plastic packaging)?**

Current global food production is the largest contributor to global warming[61], responsible for an estimated 30% of greenhouse gas emissions (GHGe)[221]. Thus, rapid and drastic changes to food systems are essential to curbing climate change[222, 223], and medical schools and universities can be key players in instigating this change[224]. By improving upon the sustainability of their own catering systems, educational institutions have the opportunity to decrease their environmental footprint, raise awareness of the massive impact the food and drink industry can have, and encourage greater societal change[224, 225].

For example, increasing the proportion of vegan and vegetarian food on offer can significantly reduce an institution's carbon footprint, as vegan and vegetarian diets are associated with fewer carbon emissions compared to a diet with high meat and dairy consumption[61, 226]. In addition, prioritising the procurement of locally grown and seasonal food can reduce food miles and support local businesses[224]. However, as well as improving sustainable procurement of food and drink, reducing its waste and packaging is also crucial to reducing (GHGe)[227, 228] – avoidable household food waste alone in the UK is responsible for 3% of total UK emissions each year[229], and disposable coffee cups are responsible for approximately 1.5 times their weight in CO_2 emissions[230].

8. **Does the medical school or associated institution apply sustainability criteria when making decisions about supply procurement?**

The processes through which sustainability can be improved in procurement comes down to a consideration of multiple factors, both when determining need and when choosing a supplier[231]; essentially, taking a list of criteria into account throughout the process. This consideration and investigation is critical, as at one point, 22% of all global emissions were the result of the supply chains of multinational corporations[232]. These criteria fall into two main categories – aspects of the item being sourced, and aspects of the company being contracted.

For the former, many considerations regard materials. For instance, single-use plastic items should generally be avoided if proper recycling and/or collection procedures are not in place, as typically non-biodegradable plastic are the most littered items[233], and these end up simply entering marine environments[234], breaking down into microplastics, and harming sea life[235] and humans[236]. Using recycled materials and trying to convert to a more circular economy can also help; it has been found that by doing so, greenhouse gas emissions can be reduced by up to 70%[237], due to the drastic decrease in new materials extracted and the energy used to do so being saved.

In addition, by prioritising the 'design for disassembly' mentality, waste reduction by recovery of materials can be improved, with case studies reporting at least 50% reuse or recycle of materials upon deconstruction[238]. This practice also allows for easier repair and maintenance, as components can be easily removed individually[238].

In terms of the company being contracted, a major concern is their energy sources, and whether they are renewable, as well as their transport methods, both of which are discussed in other metrics. It is also important to consider the distance travelled by products when finding suppliers, as transport through international regions such as by cargo ship can obfuscate true emissions statistics by up to 3%[239].

Finally, it's worth noting that the introduction and explanation of sustainability criteria to those who can make the changes is vital for successful sustainable procurement, as the biggest barrier to success is a lack of knowledge in the field. It is thus essential to ensure people are educated on sustainability criteria, in order to increase sustainability of procurement[240].

9. **Are there sustainability requirements or guidelines for events hosted at the medical school?**

The vast majority of medical school events have an inherent environmental impact. Organiser choices, such as venue, catering and promotional giveaways as well as attendee choices such as mode of transport, all contribute to the environmental profile of an event, and to fail to consider the long-term consequences of these choices on public health is ultimately at odds with the collective aim of the healthcare community.

However, desire to improve the sustainability of events has been shown[241] and guidelines could help facilitate this[242], as acknowledging the environmental impact of certain practices is vital to begin combatting them. For example, people on average only keep promotional items for around 7 months[243], and if this was highlighted, organisers may consider whether some giveaways add sufficient value to an event. In addition, up to 50% of catered food in hospitality can end up in landfill[241], generating more emissions if it's composed of a lot of meat or dairy products[244]. If organisers were made aware of this, then they may reconsider the necessity of such menus, or if catering is required at all, which could cut back on university food waste. Moreover, while it may not be always preferable, online events can negate the emissions generated by travel altogether, so it could be beneficial to ensure organisers have considered if their event could be held virtually.

10. **Does your medical school have programs and initiatives to assist with making lab spaces more environmentally sustainable?**

In general, laboratories use a significant amount of resources and generate a substantial amount of waste. With a high density of energy intensive equipment, long operational hours, and the need for ventilation, laboratories can use up to 10 times more energy per square meter than other academic spaces[245]. Likewise, water usage is also high[246], with up to 5 times more water per square meter compared to other academic spaces[247, 248]. Chemical and solid waste produced can be staggering, especially that of plastic, which has been estimated to contribute approximately 2% of all global plastic waste in 2014[249].

Research has shown that not only is it possible to drastically reduce the environmental impact of laboratories[250], but that there is also a wish to change the current situation. Moreover, as lack of awareness regarding the problem of laboratory sustainability is thought to be a key perpetuator of the

problem[251], implementing a program or initiative to assist laboratories in improving their sustainability, could really lead to significant change.

11. Does your institution's endowment investments portfolio include fossil-fuel companies?

There are many reasons why medical schools should divest from fossil fuel companies, many of which are linked to the duty they have to protect public health. With overwhelming evidence that fossil fuels threaten both public and environmental health, supporting these companies through investment is in direct and obvious conflict with the values a medical school has. Fossil fuels have been linked to a number of environmental issues that are detrimental to human health. For example, as primary contributors to CO_2 emissions (accounting for 92% of anthropogenic CO_2 emissions in the US[252]), they bear a large proportion of responsibility for the negative impact on health caused by climate change. It is also well known that they are a large cause of air pollution, particularly in the form of particulates, which is estimated to cause 4.2 million excess deaths a year[253].

The behaviour of some fossil fuel companies is also a reason to divest. For example, a few companies themselves, notably ExxonMobil, have deliberately cast doubt on the science behind climate change, and have blocked international treaties such as the Kyoto Protocol which aim to reduce our environmental impact[254]. These actions counter the concept of spreading knowledge and good science, which is valued by medical institutions, and divestment can help discourage further similar behaviour.

In fact, divestment by high profile institutions such as medical schools, reduces the social acceptability of the environmentally harmful practices of these companies, and this loss of faith is even acknowledged as "the biggest challenge … going forward" by the company Shell[255]. If this divestment was united across medical institutions, it would send a clear and powerful message to the public, that healthcare professionals believe in the need and urgency of transitioning to renewable energy. It would raise awareness of and emphasise the importance of the climate crisis and at the same time encourage the use of and research into renewable alternatives.

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