# Using Precision Public Health to Manage Climate Change: Opportunities, Challenges, and Health Justice

*Walter G. Johnson*

## Introduction

Climate change threatens human health and well-being, creating escalating challenges for public health institutions through its direct and indirect threats to population health and widening of health inequities. Without appropriate mitigation, the World Health Organization (WHO) projects that 250,000 deaths will occur globally every year from 2030 to 2050 due to hazards including climate-related heat exposure, the spread of infectious disease, coastal flooding, and malnutrition.[1] More will suffer from various morbidities during that time. Public health agencies at every level of government will be responsible for building robust health resilience and adapting to the hazards of a changing climate. Yet, adaptation efforts may suffer from barriers such as insufficient resources or comprehension of the systemic and community-specific health impacts of climate change.

Amid this mounting crisis, "precision" public health (PPH) is emerging among next generation approaches to public health practice.[2] These novel methods promise to augment public health operations by using ever larger and more robust health datasets combined with new tools for collecting and analyzing data. In a changing climate, PPH approaches could support or optimize public health surveillance, distribution of services and resources, and resiliency and emergency preparedness. Yet, the nebulous concept of PPH remains difficult to define and experts contest what it should prioritize. Even if technical and definitional obstacles could be removed, focusing on precision and emphasizing technological solutions present their own challenges that could undermine the effectiveness or legitimacy of public health interventions on climate change.

This article will begin by reviewing the systemic health threats posed by climate change and the potential value of big data-based strategies. The concept of PPH and its potential uses for climate change will then be discussed. Finally, the article will anticipate potential legal and ethical challenges to the use of PPH in the climate response and argues that a health justice perspective can promote more responsible PPH implementation.

## Systemic Threats, Scarce Resources

Climate change poses largely systemic health hazards. These systemic threats gradually and globally make

**Walter G. Johnson, J.D. M.S.T.P.,** *is a research fellow at the Sandra Day O'Connor College of Law, Arizona State University. He received a J.D. from the Sandra Day O'Connor College of Law in 2020 and a Master of Science and Technology Policy (M.S.T.P.) from Arizona State University in 2017.*



*The Journal of Law, Medicine & Ethics,* 48 (2020): 681-693. © 2020 The Author(s)
DOI: 10.1177/1073110520979374
https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

the world's many environments more dangerous to live in and increase social and psychological stress on its inhabitants. Haines and Ebi identify four primary drivers of climate-related health hazards: air pollutants, rising temperature, rising sea levels, and increasing extreme weather events.[3]

These mechanisms create various public health risks.[4] Exposure to extreme temperatures and air pollution as a result of climate change can adversely affect cardiovascular, respiratory, and mortality outcomes.[5] A warming climate will expand the habitats of disease-bearing vectors such as mosquitos and promote growing conditions for food- and water-borne pathogens.[6] Changing weather patterns will gradually inflame the severity of droughts, food insecurity, sea level rise, floods, and landslides, displacing entire communities and destroying resources.[7] Extreme weather events such as fires and hurricanes also become more likely, causing acute damage and psychosocial stressors and potentially leading to social unrest that could undermine human security by driving political instability, forced migration, or violence.

The climate crisis will impose these systemic health burdens unevenly, often falling hardest on the most vulnerable populations in low- and middle-income countries (LMICs). In identifying vulnerable populations, the WHO lists children and elderly populations; people with pre-existing health issues; those living in coastal, mountainous, or polar environments or dense urban areas; and those living in regions with "weak health infrastructure."[8] Migrants represent another vulnerable group and face compounding hardships including insufficient access to services and relegation to living in higher-risk areas when they reach a destination.[9] Within populations, climate-related threats will likely cause the greatest harm to marginalized groups, including racial and ethnic minorities and low socioeconomic status individuals.

These systemic, insidious health threats demand robust responses from public health agencies and nonstate actors. Wiley argues the diffuse and incremental health hazards of climate change require a shift from preparedness towards resilience in public health law and policy.[10] Ultimately, building effective resilience to complex climate threats will involve multiple public health instruments deployed in concert by state and nonstate actors in furtherance of the ten essential public health services, such as surveillance, preparedness, and adaptation of the built environment.[11]

Successfully deploying many of these instruments to build health resilience will rely heavily on data and require substantial public and private resources. The WHO points to multiple roles and types of modeling, assessment, and surveillance required for climate responses.[12] These include climate modeling for early warning of extreme weather events, monitoring dynamic environmental determinants of health such as air and water quality, surveillance of climate-related infectious disease, tracking morbidity and mortality, and determining the vulnerability of and risks for individual communities. Such data-intensive tools will also require appropriate health communication to ensure that policymakers and affected communities can make informed decisions about preparing and responding to climate-related hazards.

Data informing decision-making about where to distribute resources and support health services will also play critical roles in responding to climate change in the most effective way, with the fewest errors, and at the lowest cost.[13] Emergency preparedness will remain critical for responding to climate-related extreme weather events and disease outbreaks, and can call on traditional public health tools such as social distancing measures and epidemiology. Beyond traditional emergency preparedness tools, adaptation of infrastructure and the built environment to the needs of specific communities will also be necessary to manage risk.[14] Information on the health impacts of climate change in real-time may provide a foundation for considering policy options, coordinating responses, assessing the intersections of environmental and social determinants of health, or evaluating interventions deployed.[15] These data can then enable public health interventions to be refined for greater effectiveness and efficiency.

The COVID-19 pandemic has illustrated how a confluence of factors such as structural racism, disagreement over whether and how to use digital contact tracing, and misalignments between the interests of for-profit technology firms and the public health can complicate and problematize the implementation of digital technologies to serve the public health.



*The Journal of Law, Medicine & Ethics*, 48 (2020): 681-693. © 2020 The Author(s)

https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

Notably, however, even though data-driven decisions may reduce costs in the long term, LMICs may lack the initial resources necessary to adopt these tools and techniques that could benefit the highly vulnerable groups there. Nor will using big data offer a panacea. The COVID-19 pandemic has illustrated how a confluence of factors such as structural racism, disagreement over whether and how to use digital contact tracing, and misalignments between the interests of for-profit technology firms and the public health can complicate and problematize the implementation of digital technologies to serve the public health.[16]

## Precision Public Health

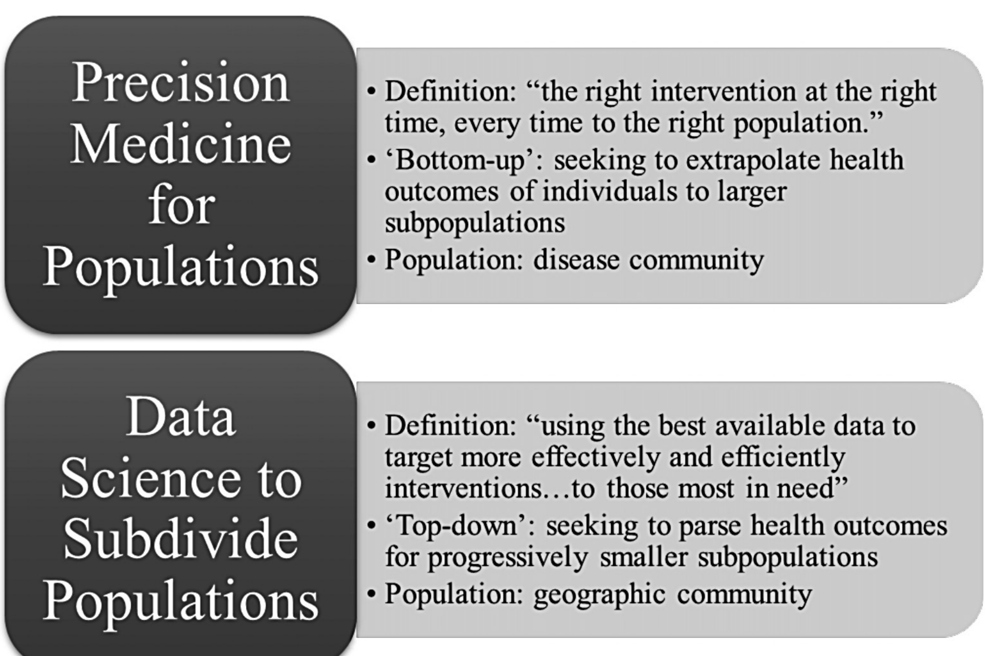
Amid the systemic challenges to public health incited by climate change and the need for more and higher quality data, scholars and policymakers have begun discussing new and bold strategies for more "precise" public and global health.[17] The growing interest in precision public health (PPH) interventions may soon capture the attention of climate-driven public health decision-makers seeking improved use of data.

The concept of PPH is new and remains contested, in both its definition and its application.[18] Broadly construed, PPH seeks to improve current public health practices and capacities by infusing them with emerging science and technologies. The term itself has begun to collect hype with substantial PPH projects recently announced by the Bill and Melinda Gates Foundation and the Rockefeller Foundation. However, PPH can mean different policies and measures to different audiences. Despite heightened interest in the last four to five years, plans for how PPH should achieve its broader goals and its underlying rationale remain imprecise. The PPH discourse has given rise to two similar but distinct ideologies backing the concept, and Figure I aims to distinguish the two.

The first model focuses on applying ideas from precision medicine to population health. In precision medicine, physicians integrate insights from an individual's genomics with their symptoms, behaviors, and environment to generate tailored treatment plans. The discipline of "public health genomics" aims to convert this precision medicine approach into population-level strategies, and gave rise to the earlier depictions of PPH.[19] Officials at the Western Australian Department of Health and US Centers for Disease Control and Prevention both pushed the expansion of public health genomics into a broader concept of PPH.[20] As an outcrop of precision medicine, this first model would describe PPH as providing "the right intervention at the right time, every time to the right population."[21]

Encoded in this definition and its roots in precision medicine is the promise of extrapolating insights about prevention and population health from new informa-

Figure I
**Two Models of Precision Public/Population Health**





*The Journal of Law, Medicine & Ethics,* 48 (2020): 681-693. © 2020 The Author(s)

https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

tion about individuals' health and interventions on individuals.[22] The US All of Us program and UK 100,000 Genomes Project, and several translational medical programs which proceeded them,[23] embody this vision of PPH by asserting that population wellbeing can be increased by learning more about the health of individuals through genomic, clinical, and behavioral data. While this first vision of PPH does seek to draw on human genomic information, its advocates describe a broader focus on big data and an emphasis on prevention by methods such as surveillance using pathogen genomics or electronic health records (EHR).[24] The interest in using EHR during the COVID-19 pandemic illustrates this first model through its assumption that data on individuals can scale up to provide information on which groups have the greatest vulnerabilities and require the most assistance.[25]

Critics of this first concept of PPH have expressed concern that scaling up insights about individuals' treatment and disease vulnerability will inevitably miss the social structures in which individuals exist.[26] Part of the problem arises from the reality that most genomic data available for analysis comes from populations of European descent, potentially exacerbating health inequities by providing low quality analysis for communities of color which may lead to under- or over- diagnosis or treatment. Proponents of precision medicine based PPH call for data collection on social and environmental determinants of health, while retaining a strong interest in genomics.[27] However, genomic myopia in methods could potentially result in overlooking non-genomic determinants of health and downgrade ongoing, successful public health efforts to address these roots of health.[28]

The second model specifically declines to use precision medicine as a starting point for defining PPH. Indeed, the most recognized definition of this second variant of PPH came from an article responding to critics of the first model, describing PPH as using "the best available data to target more effectively and efficiently interventions … to those most in need."[29]

This second vision of PPH emphasizes using big data beyond genomics, data science, and related technological tools to analyze health outcomes for the smallest subpopulations possible under those methodologies. Proponents argue that rapidly collecting more precise data on populations and using powerful data analysis tools will enable public health officials to allocate scare resources more efficiently, thereby resolving problems more effectively.[30] The promise of methods such as geospatial modeling and artificial intelligence (AI), in combination with data collection from novel sources such as smartphones, internet of things (IoT), and smart infrastructure, buttress this vision. Prioritizing big data and data science also creates an emphasis on data sharing and interoperability within the vision.[31] For this second model, genomic data can play a role but is deemphasized relative to proponents of the first vision of PPH. Recent studies have deployed this version of PPH by creating high resolution maps of child mortality in LMICs.[32] By combining and processing vast amounts of health and location data with geostatistical modeling tools, the researchers could map mortality rates to 5 km x 5 km zones, instead of at the country-level.

Criticisms of this second model of PPH have focused more on the reality that these new methods merely bolster traditional public health functions, suggesting that the moniker "precision" is redundant in public health practice and risks overhyping tools with inevitable limitations.[33] This criticism manifested during the COVID-19 pandemic with debates over whether to use digital contact tracing, which epitomizes this second model of PPH in its top-down approach of parsing larger populations for relevant subpopulations, or to proceed with more traditional methods of contact tracing which do not directly rely on private technology firms and geolocation data from mobile phones. Commentators noted public health agencies have established methods of providing contact tracing, which still act on the individual level without raising data privacy concerns and using rapidly developed tools which may have technical errors or issues.[34] While empirical data will be needed to assess whether digital contact tracing may have increased the effectiveness of pandemic responses, this example demonstrates both that precision tools often merely augment existing methods rather than creating new ones and that using digital technologies because of their "precision" can be contested when other public health methods exist which still operate on subpopulations or individuals. Yet, lessons from other emerging technologies suggests that appealing catch-all terms, such as "nanotechnology," help aggregate policy conversations and additional funding for multidisciplinary spaces.[35] The term PPH may therefore come to act as more of an organizational principle to capture existing policy tools and prove durable in the coming years, despite the contestability of viewing digital technologies as inherently precise or more precise than other tools.

Overall, both narratives of PPH may support similar projects and espouse the use of new technologies in public health, though they carry different underlying assumptions and values. These can be divided into three core differences: (1) the rationale behind the approach, (2) how subpopulations are conceived, and (3) how to use data.



*The Journal of Law, Medicine & Ethics*, 48 (2020): 681-693. © 2020 The Author(s)

https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

First, the two models adopt different approaches to PPH, where the first vision aims to begin with individuals and build up to insights about subpopulations while the second strives to begin with populations and narrow down progressively smaller subpopulations within the larger group. Second, the first vision of PPH defines populations as a group with the same disease or disease vulnerability, whereas the second model views populations as geographic entities distinct from larger political jurisdictions.

Third, both visions rely on emerging technologies for data collection and analysis but with slightly different scopes. The first model of PPH places greater value on research and identifying new routes for prevention through genomic and other types of investigation, whereas the second model instead places less emphasis on knowledge creation and stresses optimizing the use of available tools and best practices to address widespread public health issues. Additionally, while both concepts originate in Western countries, the precision medicine based PPH model grew out of use cases in industrialized countries while the second PPH model has been more grounded in applications in LMICs and global health.

## Opportunities for PPH in Climate Change

The concept of PPH has multiple potential benefits and opportunities for use in augmenting the public health response to climate change. Various emerging technologies and tools have begun to create opportunities to use big datasets in public health practice, which may be necessary for responding to the systemic, insidious threats of climate change. Already, the idea of infusing "precision" into climate-related public health approaches has entered the academic literature.[36]

PPH in climate responses could draw on new data sources, collection and aggregation methods, and analytical tools to bolster improved health resilience through preparedness and adaptation. First, new data sources such as social media posts, electronic medical records, and mobile health (mHealth) devices may prompt insights into location-specific morbidity from climate-driven outbreaks, heat waves, food scarcity, or social unrest. Falling prices of genomic sequencing techniques could also boost efforts to determine the origin or epicenter of an outbreak, especially as a warming climate permits greater vector travel and pathogen proliferation.

Second, emerging methods of collecting data, from social media scraping to IoT sensor networks, offer methods of collecting data and aggregating multiple types of data for novel insights. Collecting mortality and morbidity data with geolocation-enabled mobile phones could offer more accurate and swift information on where climate-related harms occur and where interventions could be targeted.[37] Already, some localities such as Chicago have installed IoT sensor networks to measure spatial differences in air pollution.[38] Officials at the US National Institute of standards and Technology have suggested embedding a diffuse sensor network to measure sea level rise and flooding at tight intervals along coastal regions.[39] Distributed sensor networks deployed in coastal regions and small island states could prompt improved models, identify timeframes for decision-making, and determine the most vulnerable communities for intervention. Distributed ledger technologies including blockchain could boost the security and reliability of climate-related public health data collected and allow for related data to be more readily linked and traced.[40]

Third, using new data sources and collection methods, analytical tools such as geospatial mapping and AI can assist in processing data, modeling, and decision-making around the health impacts of climate change and assessing interventions deployed. For instance, AI systems played a role in early detection and monitoring of the COVID-19 pandemic by incorporating various data sources, including scouring social media posts for depictions of illness and symptomatology clustered in geographic proximity.[41] Similar tools could potentially monitor for outbreaks of vector-, food-, or water-borne disease. AI may also enable modeling, predicting, and preparing for extreme weather events and their likely impacts on specific localities.[42]

Given the systemic scope of the public and global health challenges posed by climate change, the first vision of PPH grounded in precision medicine will not likely offer an appropriate strategy in the near future. The precision medicine based approach of extrapolating insights from individuals will likely break down if taken to the global level, as the sheer scale of variations between individuals, in their environmental and social settings, will likely render this approach prohibitively costly and time consuming. Further, too little genomic data on populations outside of developed countries appears to be available to make appropriate use of genomic insights at the global level. The prospective value of human genomic insights for adapting to climate change in the near- to mid-term term is similarly limited. These "individual-up" approaches to climate PPH may instead be most effective when combined with other individual-centric public health initiatives such community-based participatory research or citizen science, though difficulties may remain in generalizing these data to the national or global levels.

Instead, the second, more data science driven model of PPH fits better with climate applications. Using


*The Journal of Law, Medicine & Ethics,* 48 (2020): 681-693. © 2020 The Author(s)
https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

Figure 2

**Opportunities and Challenges for PPH in Climate Change**

| | Data Sourcing | Data Collection, Aggregation | Data Analysis Tools |
|---|---|---|---|
| **Opportunities** | New data types for novel insights on systemic impacts of climate change | Gathering/linking more data for precise insights on how climate change affects subpopulations | Geospatial mapping, algorithmic modeling and decision-making |
| **Potential Risks** | Failing to account for social determinants of health and obtain representative samples | Reidentification, data security, and secondary use within government or in private sector | Algorithmic bias in recommendations or decisions propagate and obscure human biases |
| **Ethical, Legal Issues** | • Inequitable outcomes<br>• Less effective interventions for most vulnerable groups | • Officials losing public trust, legitimacy<br>• Privacy/security harms and legal challenges | • Reinforcing disparate outcomes<br>• Legal challenges over fundamental rights |

any type of data, rather than looking first to human genomics, should enable PPH interventions to be deployed globally, not solely in high-income nations. The view of populations on which to intervene as geographic communities also suits climate change well, as hazards from heat waves, rising sea levels, and viral vectors will depend strongly on location and geography (though higher resolution climate models may also be needed[43]). The even newer idea of "precision" global health (PGH) is more consistent with the second vision of PPH and climate-related applications more generally, as PGH emphasizes characterizing and intervening on health determinants and disparities in precisely drawn locations across the globe.[44]

Multiple technical barriers remain before these tools can be fully appreciated, such as improving the capacities of AI and better understanding how digital data can model human behavior and behavioral change.[45] Further, data sources from laypersons such as social media posts and search terms will need to be carefully assessed and processed, as these data may report sign, symptom, and disease terms incorrectly or interchangeably. Learning lessons from missteps with resources such as Google Flu Trends will require carefully interrogating datasets and the structure and outputs of data processing tools to avoid over- or under-estimations based on faulty assumptions or meaningless patterns.[46] Yet, overall, adopting PPH and PGH strategies for addressing climate change offers the possibility of matching systemic hazards with broad-based, evidence-based responses. Whether by better prediction and preparedness for greater effectiveness, coordinating services for increased efficiency, targeting interventions to reduce liberty infringements, or automating some public health tasks to free up scare resources, PPH strategies could have promising benefits in the climate context.

## Ethical and Legal Challenges for PPH in Climate Responses

Advocates of the models of PPH (and PGH) presented above appear to assume that infusing public health with "precision" would inherently lead to better interventions in any public health arena, including climate change. Within this narrative, the opportunities of PPH may soon appeal to practitioners and policymakers seeking robust answers to the systemic challenges imposed by the changing climate. However, whether adopting PPH strategies in the climate context will improve public health outcomes is uncertain and presents both empirical and normative questions. The empirical question cannot be answered at this time, but the normative dimension requires asking whether precision will likely further the core goals of public health for addressing climate-related threats and, if so, for whom?

By emphasizing data and efficiency, PPH strategies may create opportunities but could also pose ethical and legal challenges or corrode the core purposes of public health policy. Pragmatic issues of implementation also arise, especially in LMICs where climate vulnerabilities are highest while digital resources and



*The Journal of Law, Medicine & Ethics*, 48 (2020): 681-693. © 2020 The Author(s)

https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

infrastructure with which to collect data are sparser. These potential pitfalls are discussed below in the emerging data sources, collection methods, and processing tools PPH strategies would promote in climate responses, reflected in Figure II.

*Data Sources and Social Determinants of Health*

PPH strategies would use data to define subpopulations to draw insights on how to deploy public health measures to efficiently build resilience to climate change. Yet, how to define a population for public health purposes is a contested process that reflects human values, which data science may obscure but will not eliminate. Parmet illustrates that "populations" are always constructed and can indicate different things to different people, noting the tight connection between population health and socioeconomic status and systems.[47]

Defining subpopulations based primarily on the types of data of interest for PPH risks painting over the social determinants of health. Myriad social determinants exist within highly complex systems, which vary by region and culture, and may prove recalcitrant to attempts at quantifying its effects in an algorithmic model of a large health dataset. When failing to accurately measure or correctly quantify social, economic, or cultural phenomena, and their complex intersections with health, PPH approaches can lead to uninformed or underinformed population health decisions.[48] Such decisions based on incomplete or inaccurate data may harm marginalized communities most by underreacting to a public health hazard or providing an intervention for a perceived problem, described by datasets, which poorly reflects the real health issues experienced by communities.

For example, many PPH proponents have raised interest in using smartphones or wearables as data sources to obtain information on location and health outcomes, especially in low-income countries where fewer data sources are available. However, particularly in low-income countries, men have access to and use mobile phones and the internet at higher rates than do women.[49] Similarly, the COVID-19 pandemic raised interest in high-income countries of using data from IoT sources such as thermometers with internet connectivity or smartphone geolocation tracking to monitor local infection rates. Yet collecting data and constructing subpopulations through smart thermometers, watches, or phones raises concerns about who has access to these devices and what structural conditions have resulted in the digital divide.[50]

Effectiveness or equity issues in the response to climate change could therefore result if PPH data sourcing fails to account for digital disparities and underlying social inequities, such as structural racism in the US and the perilous ways it pervades health care and health data.[51] When decision-makers have an insufficient understanding of the health struggles of less visible communities, public health interventions can overlook these marginalized groups, especially in times of crisis.[52] Women, children, migrants, and people experiencing homelessness are already vulnerable groups in a changing climate,[53] so PPH climate strategies that cannot account for their underrepresentation in datasets may underserve or entirely miss the needs of such subpopulations. Poorly designed PPH datasets could therefore result in fewer public health resources going to the groups most vulnerable to climate change. Decisions about what to measure, how to quantify social phenomenon, and what data to use, all become critical determinations of whether PPH strategies will be effective, and for whom, in the climate response.

*Data Collection, Processing, and Privacy*

PPH approaches would aim to efficiently tailor climate responses by collecting and aggregating many types of data on population health and climate indicators to discern the relative need of interventions.[54] While these methods could provide powerful insights on subpopulations, they also raise data privacy and security concerns.

Privacy harms can arise when irresponsible data collection, processing, or disclosure exposes individuals to various injuries including anxiety, discrimination, or exploitation.[55] For example, organizations such as Amnesty International have raised concerns that expanded digital surveillance during COVID-19 could lead to increased human rights violations by governments and private actors.[56] Proper data protection is therefore critical to successful public health practice, since individuals could resist undergoing diagnostics, treatment, or research or provide false or only partial information should they fear privacy harms.[57] Public health agencies that cannot deliver on privacy protections for the populations whose data they use may suffer public distrust and lose perceived legitimacy, potentially undermining the interventions that could aid those populations.

In the setting of climate change, poor privacy practices could thwart the potential benefits of PPH in addressing systemic health threats. For instance, aggregating many varieties of data may allow new and more nuanced insights about how climate change affects health. However, aggregation can also reveal or predict highly sensitive information about individuals, possibly including sexual orientation, immigration status, or substance use.[58] These extra insights


*The Journal of Law, Medicine & Ethics,* 48 (2020): 681-693. © 2020 The Author(s)
https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

heighten the costs of secondary use, where data is used for non-public health purposes such as law enforcement.[59] Should public health datasets be shared with private sector actors like Google or Apple, secondary use concerns will also follow.[60] Big data methods increase the risk of reidentifying individuals and datasets may become the targets of cyberattacks, raising issues of how to adequately secure and anonymize health and climate data. New technologies such as AI complicate these privacy and security issues further by enhancing the power of data collection and aggregation — and through bias concerns described below — though emerging privacy-enhancing technologies including "differential privacy" also show promise for safeguarding data and its use.[61]

Regulatory norms around data privacy vary heavily across jurisdictions, but generally provide some degree of exception to public health agencies.[62] Public health institutions may instead need to develop robust best practices regarding big data to fulfill ethical or statutory duties to protect privacy.[63] Private entities collecting or processing climate-related public health data could pose legal issues as well, especially under more rigorous regulatory regimes. Yet, in jurisdictions such as the US, many new types of health-related data collected with IoT sensors, mHealth devices, and social media have uncertain legal and regulatory status when captured by private actors.[64]

*Data Processing and Algorithmic Bias*

Building on data sourcing and collection issues, PPH methods could also provide a platform for algorithmic bias to enter the public health processes for adapting to climate change. Many AI algorithms learn to perform various functions by parsing data in search of patterns, which the AI can then use to interpret and make decisions about new data it encounters.[65] However, AI platforms do not understand broader concepts such as health or social systems and generally cannot explain what factors or patterns they used to make a decision, described as the "black box" problem. If the datasets AI tools learn from reflect human biases against marginalized groups, such as racial and sexual minorities, the algorithm may incorporate that prejudice without readily explaining so to human observers.[66] Accounting for existing biases in the data AI learn from is a challenging process and even efforts to correct for biases in underlying data can exacerbate or confound algorithmic bias if not carefully and thoughtfully implemented.[67]

When AI platforms learn from population health data that do not represent its target population or do not account for social and structural issues, these algorithms can propagate human biases against underserved populations.[68] For example, a recent study of a proprietary AI platform used in US hospitals found that using the algorithm resulted in up to 46 percent of Black patients receiving less medical attention than white patients with similar health needs.[69] The algorithm used health care expenses as a heuristic for health outcomes, but failed to recognize that the US health industry systematically spends fewer resources on Black patients due to implicit or overt individual and structural biases. Accordingly, the algorithm recommended that Black patients who needed greater medical attention receive only as much care as their comparatively healthier white counterparts.[70]

Adopting a PPH strategy for climate hazards could similarly contribute to inequitable outcomes. If public health officials use AI to assist in decisions about what communities are in the greatest need of climate adaptation measures, algorithms driven by biased data could widen resilience gaps rather than close them. By basing decisions or recommendations, at least in part, on incomplete or unrepresentative datasets and factors such as the extent of resources communities have received in the past, AI could amplify inequities produced by climate change by diverting resources away from marginalized communities. Through such "digital redlining," biased emergency preparedness and response efforts could leave already vulnerable communities more exposed to extreme weather events or outbreaks of climate-related infectious disease.[71]

Public health agencies relying on potentially biased algorithms for climate adaptation efforts could trigger legal challenges as well as ethical and governance issues. Constitutional and human rights norms including due process, nondiscrimination, data privacy, and effective remedies each provide some grounds for objection to algorithms making decisions about public benefits, such as public health.[72] Liability for public health agencies could also arise should biased AI platforms make decisions on behalf of agencies which lead to inequitable outcomes. However, in practice, governments have been slow to respond to these concerns and the limited litigation on these norms has struggled to make significant impacts.[73] Statutory and regulatory privacy or civil rights protections could also be engaged, with results likely varying across jurisdictions.

## Health Justice as a Guide for PPH Climate Responses

As an emerging strategy, PPH presents both opportunities and challenges. If PPH can deliver significant communal benefits, then these challenges alone may not provide sufficient reason to categorically prohibit precision climate responses.[74] However, social justice



*The Journal of Law, Medicine & Ethics*, 48 (2020): 681-693. © 2020 The Author(s)

https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

and good governance principles demand attention to health inequities in any current or proposed public health policy. Avoiding challenges identified above may also prevent potential legal challenges to PPH interventions, enabling swifter implementation. Justifying the use of PPH tools in the climate response will require anticipating disparities before they occur and modifying the design of proposed PPH interventions to mitigate such disparities.

Health justice offers a promising framework for guiding more equitable uses of PPH for responding to climate-driven health hazards. The concept of health justice embodies both a theoretical and pragmatic orientation towards equitably promoting health for all through understanding health as a product of myriad factors outside individuals' control.[75] Wiley describes health justice as a lens for critically evaluating (1) how various social determinants of health will mediate public health interventions, (2) how systemic biases and structural barriers necessitate collective responsibility for public health, and (3) how to encourage meaningful community participation in designing and deploying interventions.[76] In previous work, health justice has been used to diagnose health inequities in existing systems, primarily in the US, and prescribe solutions.[77]

The recent advent of health justice builds on lessons learned from environmental justice and complements other social justice frameworks applicable to the health hazards of a changing climate, most notably climate justice. Various conceptualizations of climate justice stress a rights-based approach to ensuring multigenerational wellbeing, development rights for LMICs, accountability for historic contributors, and equity in efforts to transition towards a more sustainable global economy.[78] This article emphasizes a health justice approach to center the health consequences of climate change and identify potential solutions trained on health, rather than climate justice's broader focus on development and sustainable economies. However, the climate justice tenants of multigenerational wellbeing and equitable treatment of LMICs must augment any health justice approach applied to climate change, especially as development and economic stability are intimately linked with health. Gostin calls for a more global health justice to animate global governance, one which declares that "human health is a globally shared responsibility, reflecting common risks and vulnerabilities — an obligation of health justice that demands a fair contribution from everyone."[79] Health justice for climate change and its systemic risks will require characterizing social determinants of health, collective responsibility, and participatory action as concepts which extend beyond any one generation or jurisdiction.

Here, Wiley's three elements of health justice can help anticipate how PPH could most likely create or worsen health inequities in the future and illuminate opportunities for mitigating inequitable outcomes. This method is used below to identify two examples of how health justice can guide more responsible PPH in climate responses.

*Representation in Data as a Determinant of Health*

With the advent of precision climate interventions, the capacity to contribute to and be reflected in public health datasets will become a determinant of health alongside access to health care. As discussed above, decisions on how to collect data and what to measure can have deep significance for who is represented in the resulting datasets, in turn controlling whose needs will become visible targets for interventions and whether that visibility reflects the actual level of need.[80]

Accordingly, public health officials collecting and aggregating PPH data for climate responses must consider how access to the internet, a mobile phone, or an IoT device will result in underrepresentation, and for whom, and either modify data collection or data interpretation methods accordingly. Deploying health in all policies (HiAP)[81] could support better representation in PPH data by coordinating various government actors to close the digital divide and consider these and other social factors when collecting data with potential relevance to PPH. Especially at the regional, supranational, and global levels, policymakers should recall historic and structural barriers to accessing digital infrastructure and ensure LMICs receive needed support in implementing best practices in PPH.

Ensuring representative samples in climate-health datasets will also require securing the public's trust, especially marginalized groups, that their data will not be used to harm them or their communities. PPH projects may build legitimacy by engaging with local communities to identify their privacy concerns and striving to include underrepresented groups in the intervention design process. Notably, the timescale of climate change will require public officials to regularly engage with communities to build trust and capacity over time and across generations. Strong and transparent privacy controls on PPH endeavors could contribute to building trust by collecting no more data than is needed and notifying the public on all intended uses for particular types of data, and what entities will have access to the datasets.[82] Adopting a collective responsibility mentality requires realizing that placing the onus of privacy protections on individuals,


*The Journal of Law, Medicine & Ethics,* 48 (2020): 681-693. © 2020 The Author(s)
https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

such as through opt in or out tools, will never be sufficient to engender trust because of the limited power and options individuals have over their data.[83]

Health justice encourages looking beyond solely access to health care as a determinant of health, though universal and affordable care remains critical to health justice and a robust climate response.[84] Further, universal health care offers potential benefits for more equitable PPH, as potential data sources such as medical records will become more inclusive when underrepresented groups gain improved access to health services. Pushing towards robust universal health care remains a challenging feat for any state and may require considerable structural reform in arenas beyond health, including finance and intellectual property.[85] Strategies to wield or construct constitutional and human rights to health care and public health services may contribute to these efforts.[86]

Precision strategies for protecting the public health could more effectively or efficiently address the systemic threats of climate change, but may also propagate or exacerbate health disparities for populations most vulnerable in a changing climate. Rather than discarding the idea of PPH altogether, the lens of health justice — when situated in a broader climate and social justice approach — offers promise for guiding responsible uses of PPH to alleviate climate-related mortality and morbidity.

*Collective Responsibility, Participatory Action for Algorithmic Bias*

Algorithmic bias is a result of not only systemic underrepresentation, but misrepresentation in datasets, developer biases, and failure to account for social and environmental determinants of health during data processing. Black box problems obscure which data and factors AI rely on to make decisions, which can conceal bias in datasets and data collection methods. Further, many algorithms procured for public uses, such as for recommendations on criminal sentencing, have involved proprietary software or datasets which can deny individuals an explanation of their outcomes.[87] Mitigating these issues of algorithmic bias in any proposed PPH climate tool extends beyond any individual or group's capacity to change their behaviors, instead militating a collective responsibility and participatory approach.

To fulfill health justice's call for collective responsibility, public health agencies can strive to promote explainability in algorithms for PPH climate interventions. Technical efforts to render AI more explainable or interpretable hold promise for probing an algorithm's otherwise opaque reasoning.[88] For climate PPH purposes, officials can consider emerging options and best practices which may include using algorithms designed to be "inherently interpretable" or calling on methods to break down the decision-making steps which occur within an AI's black box.[89] Using more explainable AI for PPH purposes could assist officials in detecting whether an algorithm uses biased data or discriminatory assumptions arising from data, allowing them to better evaluate AI output and improve the algorithms. Full explainability in AI remains an aspirational and contestable goal,[90] but public health agencies should prioritize developing or procuring AI crafted with explainability or interpretability as core goals. Public health agencies should also avoid procuring and using proprietary software for PPH interventions, as proprietary software will frustrate efforts to review AI platforms for bias and could undercut public trust in climate resilience efforts.

Health justice's call for community participation would also support taking affirmative measures to include community members in the PPH product development and assessment processes, in addition to including public health officials with an understanding of how technological tools and community participation both affect public health interventions. A majority of professionals working on AI and other emerging digital technologies are white, male, and from wealthy backgrounds.[91] This paucity of experiences may increase the risk of bias or inaccuracy in PPH tools through systemically neglecting to account for various determinants of health related to climate change. For example, during the 2014-2016 West African Ebola crisis, a US-based team made the faulty assumption — based on American culture — that individuals in Sierra Leone would consistently use a single mobile phone. Instead, mobile devices were "traded, loaned, and passed among family and friends," which


*The Journal of Law, Medicine & Ethics*, 48 (2020): 681-693. © 2020 The Author(s)
https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

severely complicated the use of phone-based location data to track and intervene on individuals.[92]

Health justice principles therefore call for developers to directly engage with communities who would be affected by their PPH tools to ensure local concerns are built into the resulting algorithms and ferret out bias in training data or outcomes. Especially in the setting of climate applications of PPH, developers should repeatedly engage with communities after implementation to ensure outcomes are consistent with the needs and interests of communities over time and across generations. Promoting diversity and inclusion in software engineers, project managers, and other digital professionals may also support this goal by shepherding different insights on climate and health into algorithmic development.[93] Attention to community participation should be heightened further when Western entities develop PGH tools for lower-income countries. Here, engagement with community members and decision-makers will be critical for creating useful interventions which local groups can find acceptable.[94] Indeed, rather than developing tools "for" populations in low-income countries, a global health justice framework calls for developing potential PGH tools "with" those who would be impacted by their use.

## Conclusion and Recommendations

Precision strategies for protecting the public health could more effectively or efficiently address the systemic threats of climate change, but may also propagate or exacerbate health disparities for populations most vulnerable in a changing climate. Rather than discarding the idea of PPH altogether, the lens of health justice — when situated in a broader climate and social justice approach — offers promise for guiding responsible uses of PPH to alleviate climate-related mortality and morbidity. Critically, efforts to anticipate PPH challenges and modify interventions to ensure that benefits are enjoyed equitably must begin early in the development of PPH tools and strategies and continue across generations. Emerging efforts in the governance of big data, AI, and other digital technologies at all levels of government should specifically consider the unique policy facets of these budding technologies as applied to public health and climate change, and public health agencies should build capacity accordingly. Mobilizing public health law, policy, and ethics through lenses akin to health justice can guide these efforts to forecast and alleviate PPH challenges with the participation of communities who could benefit the most from these interventions.

### Note

The author has no conflicts of interest to declare.

### Acknowledgements

With the usual qualifications, I would like to thank Madeline Morcelle, Guy Cardineau, James G. Hodge, Jr., and Gary E. Marchant, as well as the anonymous reviewers and special issue editors, for their invaluable comments and suggestions on earlier drafts of this article.

### References

1. World Health Organization, "Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s," 2014, *available at* <https://apps.who.int/iris/handle/10665/134014> (last visited March 8, 2020).
2. F. Kee and D. Taylor-Robinson, "Scientific Challenges for Precision Public Health," *Journal of Epidemiology & Community Health* 74, no. 4 (2020): 311-314.
3. A. Haines and K. Ebi, "The Imperative for Climate Action to Protect Health," *New England Journal of Medicine* 380, no. 3 (2019): 263-273.
4. U.S. Global Change Research Program, "The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment," April 2016, *available at* <https://health2016.globalchange.gov/> (last visited March 8, 2020).
5. C. Liu et al., "Ambient Particulate Air Pollution and Daily Mortality in 652 Cities," *New England Journal of Medicine* 381, no. 8 (2019): 705-715.
6. World Health Organization, "Climate Change and Human Health: Risks and Responses," 2003, *available at* <https://www.who.int/globalchange/publications/climchange.pdf> (last visited March 7, 2020).
7. S. Dangerdorf et al., "Persistent Acceleration in Global Sea-Level Rise Since the 1960s," *Nature Climate Change* 9 (2019): 705-710; C. Xu et al., "Future of Human Climate Niche," *Proceedings of the National Academy of Sciences of the United States of America* 117, no. 2 (2020): 11350-11355.
8. World Health Organization, "Climate Change and Health," February 1, 2018, *available at* <www.who.int/health-topics/climate-change> (last visited Jan. 29, 2020).
9. Intergovernmental Panel on Climate Change, "Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects," 2014, *available at* <https://www.ipcc.ch/report/ar5/wg2/> (last visited Jan. 29, 2020).
10. L.F. Wiley, "Adaptation to the Health Consequences of Climate Change as a Potential Influence on Public Health Law and Policy: From Preparedness to Resiliency," *Widener Law Review* 15, no. 2 (2010): 483-519.
11. H. Frumkin et al., "Climate Change: The Public Health Response," *American Journal of Public Health* 98, no. 3 (2008): 435-445.
12. World Health Organization, "Operational Framework for Building Climate Resilient Health Systems," 2015, *available at* <https://www.who.int/globalchange/publications/building-climate-resilient-health-systems/en/> (last visited March 9, 2020)
13. K.L. Ebi et al., "Adaptation to Climate Variability and Change from a Public Health Perspective," in K.L. Ebi, J. Smith and I. Burton, eds., *Integration of Public Health with Adaptation to Climate Change* (Boca Raton: Taylor & Francis, 2005): at 1-15.
14. U.S. Department of Health and Human Services, "Primary Protection: Enhancing Health Care Resilience for a Changing Climate," December 2014, *available at* <https://toolkit.climate.gov/topics/human-health/building-climate-resilience-health-sector> (last visited March 10, 2020).
15. M. Pascal et al., "How Can a Climate Change Perspective Be Integrated into Public Health Surveillance?" *Public Health* 126, no. 8 (2012): 660-667.



*The Journal of Law, Medicine & Ethics,* 48 (2020): 681-693. © 2020 The Author(s)

https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

16. See, e.g., N. Ram and D. Gray, "Mass Surveillance in the Age of COVID-19," *Journal of Law and the Biosciences* 7, no. 1 (2020): doi: 10.1093/jlb/lsaa023; C. Ross, "Covid-19 Apps and Wearables Are Everywhere. Can They Actually Benefits Patients?" *Stat News*, August 4, 2020, *available at* <https://www.statnews.com/2020/08/04/covid19-wearables-apps-patient-care/> (last visited Aug. 10, 2020).
17. Editorial, "Precision Global Health: Beyond Prevention and Control," *The Lancet Global Health* 5, no. 1 (2017): e1.
18. M. Chowkwanyun et al., "'Precision' Public Health — Between Novelty and Hype," *New England Journal of Medicine* 379, no. 15 (2018): 1398-1400; D. Taylor-Robinson and F. Kee, "Precision Public Health — The Emperor's New Clothes," *International Journal of Epidemiology* 48, no. 1 (2019): 1-6.
19. C. M. Molster et al., "The Evolution of Public Health Genomics: Exploring Its Past, Present, and Future," *Frontiers in Public Health* 6, art. 247 (2018): 1-11.
20. T.S. Weeramanthri et al., "Editorial: Precision Public Health," *Frontiers in Public Health* 6, art. 121 (2018): 1-3.
21. M.J. Khoury, "Precision Public Health: What Is It?" US Centers for Disease Control and Prevention, May 15, 2018, *available at* <https://blogs.cdc.gov/genomics/2018/05/15/precision-public-health-2/> (last visited Jan. 28, 2020).
22. See E.J. Topol, "Individualized Medicine from Prewomb to Tomb," *Cell* 157, no. 1 (2014): 241-253.
23. G.S. Ginsburg and K.A. Phillips, "Precision Medicine: From Science to Value," *Health Affairs* 37, no. 5 (2018): 694-701.
24. M.J. Khoury et al., "Precision Public Health for the Era of Precision Medicine," *American Journal of Preventative Medicine* 50, no. 3 (2016): 398-401.
25. K. Stoeger and M. Schmidhuber, "The Use of Data from Electronic Health Records in Times of Pandemic — A Legal and Ethical Assessment," *Journal of Law and the Biosciences* 7 (2020): doi: 10.1093/jlb/lsaa041.
26. R. Bayer and S. Galea, "Public Health in the Precision-Medicine Era," *New England Journal of Medicine* 373, no. 6 (2018): 499-501.
27. M.J. Khoury et al., "From Public Health Genomics to Precision Public Health: A 20-Year Journey," *Genetics in Medicine* 20, no. 6 (2018): 574-582.
28. R. Cooper and N. Paneth, "Will Precision Medicine Lead to a Healthier Population?" *Issues in Science and Technology* 36, no. 2 (2020), *available at* <https://issues.org/precision-medicine/> (last visited September 28, 2020).
29. R. Horton, "Offline: In Defense of Precision Public Health," *The Lancet* 392, no. 10157 (2018): 1504.
30. S.F. Dowell et al., "Four Steps to Precision Public Health," *Nature* 540, no. 7632 (2016): 189-191.
31. S. Dolley, "Big Data's Role in Precision Public Health," *Frontiers in Public Health* 6, art. 68 (2018): 1-12.
32. R. Burstein et al., "Mapping 123 Million Neonatal, Infant and Child Deaths Between 2000 and 2017," *Nature* 574, no. 7778 (2019): 353-358.
33. See Chowkwanyun et al., *supra* note 18.
34. See Ram and Gray, *supra* note 16.
35. G.A. Hodge et al., "Nanotechnology: Rhetoric, Risk and Regulation," *Science and Public Policy* 41, no. 1 (2014): 1-14.
36. A. Hansen and P. Bi, "Climate Change Adaptation: No One Size Fits All," *The Lancet Planetary Health* 1, no. 9 (2017): e353-e354.
37. See Dowell et al., *supra* note 30.
38. J. Clark, "Big Data, Pollution and the IoT," IBM Internet of Things Blog, November 7, 2017, *available at* <https://www.ibm.com/blogs/internet-of-things/iot-pollution-initiatives/> (last visited Mar. 22, 2020).
39. D. Loftis, "StormSense: A New Integrated Network of IoT Water Level Sensors in the Smart Cities of Hampton Roads, VA," *Marine Technology Society Journal* 52, no. 2 (2018): 56-67.
40. D.S.W. Ting et al., "Digital Technology and COVID-19," *Nature Medicine* 26, no. 4 (2020): 459-461.
41. C. Ross, "In Coronavirus Response, AI Is Becoming a Useful Tool in Global Outbreak, Data Experts Say," Stat News, January 29, 2020, *available at* <https://www.statnews.com/2020/01/29/coronavirus-response-artificial-intelligence-becoming-useful/> (last visited Jan. 29, 2020).
42. A. McGovern et al., "Using Artificial Intelligence to Improve Real-Time Decision-Making for High Impact Weather," *Bulletin of the American Meteorological Society* 98, no. 10 (2017): 2073-2090.
43. See T. Palmer, "Build High-Resolution Global Climate Models," *Nature* 515, no. 7527 (2014): 338-339.
44. See Editorial, *The Lancet Global Health*, *supra* note 17.
45. See Kee and Taylor-Robinson, *supra* note 2.
46. D. Lazer et al., "The Parable of Google Flu: Traps in Big Data Analysis," *Science* 343, no. 6176 (2014): 1203-1205.
47. W.E. Parmet, *Populations, Public Health, and the Law* (Washington, DC: Georgetown University Press, 2009): at 13-19.
48. M. Kennedy and L. Mamo, "The Imaginary of Precision Public Health," *Medical Humanities* 46, no. 3 (2019): 192-203.
49. GSMA, "Connected Women: The Mobile Gender Gap Report 2019," February 2019, *available at* <https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/02/GSMA-The-Mobile-Gender-Gap-Report-2019.pdf> (last visited March 13, 2020).
50. J.C. Hu, "So About That Thermometer Data That Says Fevers Are on the Decline…," *Slate: Future Tense*, April 6, 2020, *available at* <https://slate.com/technology/2020/04/kinsa-smart-thermometer-data-fevers-covid19.html> (last visited April 7, 2020).
51. L.E. Egede and R.J. Walker, "Structural Racism, Social Risk Factors, and Covid-19 — A Dangerous Convergence for Black Americans," *New England Journal of Medicine* (2020): doi: 10.1056/NEJMp2023616.
52. E.G. Ellis, "For Homeless People, Coivd-19 Is Horror on Top of Horror," *Wired*, April 2, 2020, *available at* <https://www.wired.com/story/coronavirus-covid-19-homeless/> (last visited April 3, 2020).
53. See World Health Organization, *supra* note 8.
54. See Dowell et al., *supra* note 30.
55. D.J. Solove, "A Taxonomy of Privacy," *University of Pennsylvania Law Review* 154, no. 3 (2006): 447-560.
56. Amnesty International, "COVID-19, Surveillance and the Threat to Your Rights," April 3, 2020, *available at* <https://www.amnesty.org/en/latest/news/2020/04/covid-19-surveillance-threat-to-your-rights/> (last visited Aug. 3, 2020).
57. L.O. Gostin, J.G. Hodge, Jr., and R.O. Valdiserri, "Information Privacy and the Public's Health: The Model State Public Health Privacy Act," *American Journal of Public Health* 91, no. 9 (2001): 1388-1392.
58. N. Kshetri, "Big Data's Impact on Privacy, Security and Consumer Welfare," *Telecommunications Policy* 38, no. 11 (2014): 1134-1145.
59. P. Karp, "Government Refuses Police Request for Access to Australian Coronavirus Contact Tracing App," *The Guardian*, April 23, 2020, *available at* <https://www.theguardian.com/australia-news/2020/apr/23/government-rules-out-police-having-any-access-to-australian-coronavirus-contact-tracing-app> (last visited April 27, 2020).
60. N. Kobie, "Everyone Should Be Worried by Big Tech's Huge NHS Data Grab," *Wired*, December 16, 2019, *available at* <https://www.wired.co.uk/article/google-apple-amazon-nhs-health-data> (April 6, 2020).
61. U.S. National Science & Technology Council, "Artificial Intelligence and Cybersecurity: Opportunities and Challenges," March 2020, *available at* <https://www.nitrd.gov/pubs/AI-CS-Tech-Summary-2020.pdf> (last visited Aug. 3, 2020).
62. J.H. Thrope and E.A. Gray, "Big Data and Public Health: Navigating Privacy Laws to Maximize Potential," *Public Health Reports* 130, no. 2 (2015): 171-175.
63. T. Chan et al., "The UK National Data Guardian for Health and Care's Review of Data Security, Consent and Opt-Outs: Leadership in Balancing Public Health with Rights to Pri-




*The Journal of Law, Medicine & Ethics*, 48 (2020): 681-693. © 2020 The Author(s)

https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press

vacy?" *BMJ Health & Care Informatics* 23, no. 3 (2016): 627-632.
64. I.G. Cohen and M.M. Mello, "Big Data, Big Tech, and Protecting Patient Privacy," *JAMA* 322, no. 12 (2019): 1141-1142.
65. Y. LeCun et al., "Deep Learning," *Nature* 521, no. 7553 (2015): 436-444.
66. R. Benjamin, *Race After Technology: Abolitionist Tools for the New Jim Code* (Cambridge, UK: Polity Press, 2019): at 40-48.
67. D.A. Vyas, L.G. Eisenstein, and D.S. Jones, "Hidden in Plain Sight — Reconsidering the Use of Race Correction in Clinical Algorithms," *New England Journal of Medicine* 383, no. 9 (2020): 874-882.
68. *Id.*
69. Z. Obermeyer et al., "Dissecting Racial Bias in an Algorithm Used to Manage the Health of Populations," *Science* 366, no. 6464 (2019): 447-453.
70. R. Benjamin, "Assessing Risk, Automating Racism," *Science* 366, no. 6464 (2019): 421-422.
71. V. Janeja, "Predicting the Coronavirus Outbreak: How AI Connects the Dots to Warn About Disease Threats," *The Conversation*, March 3, 2020, *available at* <https://theconversation.com/predicting-the-coronavirus-outbreak-how-ai-connects-the-dots-to-warn-about-disease-threats-130772> (last visited March 3, 2020).
72. Council of Europe, "Algorithms and Human Rights: Study on the Human Rights Dimensions of Automated Data Processing Techniques and Possible Regulatory Implications," March 2018, *available at* <https://rm.coe.int/algorithms-and-human-rights-en-rev/16807956b5> (last visited Apr. 3, 2020).
73. S.K. Katyal, "Private Accountability in the Age of Artificial Intelligence," *UCLA Law Review* 66, no. 1 (2019): 54-141.
74. J.G. Hodge, Jr., "Revisiting the Renaissance in Public Health Law," *Journal of Law, Medicine & Ethics* 46, no. 4 (2018): 1031-1033.
75. S. Venkatapuram, *Health Justice: An Argument from the Capabilities Approach* (Cambridge, UK: Polity Press, 2011): at 4-5, 16.
76. L.F. Wiley, "Health Law as Social Justice," *Cornell Journal of Law and Public Policy* 24, no. 1 (2014): 47-105.
77. E.A. Benfer et al., "Health Justice Strategies to Combat the Pandemic: Eliminating Discrimination, Poverty, and Health Inequity During and After COVID-19," *Yale Journal of Health Policy, Law, and Ethics* (forthcoming), *available at* <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3636975> (last visited Aug. 10, 2020); E.A. Benfer, "Health Justice: A Framework (and Call to Action) for the Elimination of Health Inequity and Social Injustice," *American University Law Review* 65, no. 2 (2015): 275-351.
78. D. Schlosberg and L.B. Collins, "From Environmental Justice to Climate Justice: Climate Change and the Discourse of Environmental Justice," *WIREs Climate Change* 5, no. 3 (2014): 359-374.
79. L.O. Gostin, *Global Health Law* (Cambridge, MA: Harvard University Press, 2014): at 19-20.
80. See, e.g., M. Gates, "Sexist and Incomplete Data Hold Back the World's COVID-19 Response," *Stat News*, July 30, 2020, *available at* <https://www.statnews.com/2020/07/30/sexist-and-incomplete-data-hold-back-the-worlds-covid-19-response/> (last visited Aug. 3, 2020).
81. L. Rudolph et al., "Health in All Policies: A Guide for State and Local Governments," *available at* <https://www.apha.org/topics-and-issues/health-in-all-policies> (last visited May 7, 2020).
82. M. Ienca and E. Vayena, "On the Responsible Use of Digital Data to Tackle the COVID-19 Pandemic," *Nature Medicine* 26, no. 4 (2020): 463-464.
83. C. Warzel, "Privacy Is Not your Responsibility," *New York Times*, Sept. 17, 2019, *available at* <https://www.nytimes.com/2019/09/17/opinion/alabama-app-privacy.html> (last visited May 7, 2020).
84. L.F. Wiley, "From Patient Rights to Health Justice: Securing the Public's Interest in Affordable, High-Quality Care," *Cardozo Law Review* 37, no. 3 (2016): 833-890.
85. S.K. Sell, "21st-Century Capitalism: Structural Challenges for Universal Health Care," *Globalization and Health* 15 (Suppl. 1), art. no. 76 (2019): 1-9.
86. J.G. Hodge, Jr. et al., "Constitutional Cohesion and the Right to Public Health," *University of Michigan Journal of Law Reform* 53, no. 1 (2019): 173-225.
87. See A. Liptak, "Sent to Prison by a Software Program's Secret Algorithms," *New York Times*, May 1, 2017, *available at* <https://www.nytimes.com/2017/05/01/us/politics/sent-to-prison-by-a-software-programs-secret-algorithms.html> (last visited May 11, 2020).
88. A. Adadi and M. Berrada, "Peeking Inside the Black-Box: A Survey on Explainable Artificial Intelligence (XAI)," *IEEE Access* 6 (2018): 52138-52160.
89. U.K. Royal Society, "Explainable AI: The Basics," November 2019, *available at* <https://royalsociety.org/-/media/policy/projects/explainable-ai/AI-and-interpretability-policy-briefing.pdf> (last visited Aug. 10, 2020).
90. T. Miller, "Explanation in Artificial Intelligence," *Artificial Intelligence* 267 (2019): 1-38.
91. K. Crawford et al., "AI Now 2019 Report," AI Now Institute, December 2019, *available at* <https://ainowinstitute.org/AI_Now_2019_Report.pdf> (last visited May 9, 2020).
92. S.L. Erikson, "Cell-Phones ff Self and Other Problems with Big Data Detection and Containment During Epidemics," *Medical Anthropology Quarterly* 32, no. 3 (2018): 315-339.
93. K.N. Johnson, "Automating the Risk of Bias," *George Washington Law Review* 87, no. 5 (2019): 1214-1271.
94. See M. Leach, I. Scoones, and B. Wynne, eds., "Introduction: Science, Citizenship and Globalization," in M. Leach, I. Scoones and B. Wynne, eds., *Science and Citizens: Globalization and the Challenge of Engagement* (New York, NY: Zed Books, 2005): 3-14.


*The Journal of Law, Medicine & Ethics,* 48 (2020): 681-693. © 2020 The Author(s)
https://doi.org/10.1177/1073110520979374 Published online by Cambridge University Press