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Commentary

# Pandemics, policy, and the power of paradigm: will COVID-19 lead to a new scientific revolution?

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ABSTRACT

Critical historical analysis of the 19th-century cholera and 21st-century coronavirus-19 (COVID-19) pandemics suggests that in conflicts over pandemic-mitigation policies, the professional backgrounds of principal opponents reveal dominant and minority scientific paradigms, presaging possible epistemological shifts. Epistemic conflict over cholera helped spur biomedical expertise as the dominant paradigm for U.S. public health science and policy beginning in the 20th century. This paradigm was reflected in federal government reliance on infectious disease physicians as the primary scientific decision makers in the COVID-19 pandemic. Similarly, epistemic conflict over challenges to behavioral and social well-being in 2020 may highlight discordance between the dominant biomedical paradigm used in making federal policy and the inherently holistic impact of that policy on population health, suggesting need for a new paradigm of multidisciplinary scientific engagement. Because population-wide public health initiatives affect many aspects of health—physiological, psychological, behavioral, and social—that are best measured and interpreted by experts in these respective fields, multidisciplinary scientific engagement would facilitate optimal, holistic evaluation of policy benefits and harms. This multidisciplinary approach, analogous to that currently recommended in medical management of chronic disease, would advance epidemiological research to inform evidence-based policy for public health crises in which U.S. population-wide interventions are contemplated.



## Introduction

A historical account familiar to contemporary epidemiologists tells of the March 1855 appearance of John Snow, a prestigious London anesthesiologist, before a Select Committee of Parliament on behalf of a curious set of businesses: gas-works, soap-boilers, and other producers of "offensive gasses proceeding from putrefying materials"[1,p. 95] well-known then as the atmospheric hazard, *miasma* [2]. Snow's investigations had suggested the deadly cholera pandemic raging through Europe was caused, he told skeptical committee members, not by *miasmatic* stench as England's prominent public health experts had concluded, but by a "cholera poison" contained in drinking water contaminated by "the excretions of the sick"[3,pp. 8, 29].

Although Snow had no way of knowing it, his conclusion represented tenuous first steps toward scientific revolution, evident in the contrast between simplistic *miasma* theory and contemporary biomedical understanding of infectious disease. Yet, just as public panic over the terrifying "fatal march"[4, p. 171] of cholera planted the seeds of a radical shift in medical epistemology—shared knowledge of disease and its treatment—so today's coronavirus-19 (COVID-19) pandemic may prompt a new epistemological shift.

In this critical historical analysis and commentary, I consider both pandemics, and the policies intended to mitigate them, through the lens of "scientific revolution," the term given by philosopher Thomas Kuhn to epistemological shifts so profound that they fundamentally alter the entire research enterprise: topic selection, data collection, analysis, and interpretation [5]. (See Web Appendix for additional annotated bibliographical references.) After reviewing competing epistemologies in each pandemic era, I conclude that an important epistemological shift in American public health science may be underway, profoundly affecting the

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scope, design, and interpretation of translational epidemiological research.

### *Reaction to the "cholera poison" hypothesis*

Snow's contemporary status as epidemiological hero stands in sharp contrast to the vicious reaction to his testimony in 1855, perhaps partly because the political context was a debate over environmental reforms consistent with prevailing medical norms and strongly supported by health officials [6]. Editors of *The Lancet* openly mocked Snow, describing him as "treasonable" to science [7,p. 634] and declaring that "the well whence Dr. Snow draws all sanitary truth is the main sewer. … In riding his hobby very hard, he has fallen down through a gully-hole and has never since been able to get out again" [7,p. 635].

A corrected obituary for Snow, published by *The Lancet* 155 years after his death as a form of apology for the "surprising contempt" [6,p. 1269] expressed by its editors, emphasized the social context of the time: consensus among most physicians that *miasma* from a variety of sources, sometimes including tainted water, caused cholera [6,8]. For example, an 1855 report of London's Medical Council to then-President of the General Board of Health, Benjamin Hall, noted that the "foul state of the Thames [River]" had contributed to the cholera epidemic of 1854, but only by causing *miasma*: it had "[rendered] the atmosphere impure"[8,p. 4]. The report also firmly ruled out "contamination of water with the excretions of the sick" as a cause and noted that the "suddenness of the outbreak, its immediate climax, and short duration, all point to some atmospheric or other widely-diffused agent still to be discovered …" [8,p. 7].

The medical community was not alone in this view. An established position of *miasma* in the public imagination was exemplified in the phenomenon of "cholera cloud" sightings, widespread internationally throughout most of the 19th century [9]. Arising from a variety of influences, including earlier beliefs about "plague clouds" and medical literature on atmospheric *miasma*, sightings of cholera clouds and mists of various colors were thought to signal the terrifying prospect of an impending epidemic [9]. At the time of Snow's testimony, cholera clouds routinely imbued public representations of the disease, from artwork depicting them as large, ominous black mists to frequent press accounts of clouds shortly preceding outbreaks [9].

Given these perceptions, it is not surprising that public reaction to Snow's conclusions was, like that of medical and public health experts of the time, skeptical. When a London Board of Guardians, reluctantly and only at Snow's urging, removed the handle of a now-infamous pump on Broad Street in 1854 because it was served by what Snow had correctly concluded was a contaminated water supply, local residents scoffed at the elimination of what was reputed to be the area's purest and most reliable source of drinking water [10,11].

Notably, the Italian physician and anatomist Filippo Pacini had published a paper in 1854 that documented a comma-shaped organism in the intestinal mucosa of cholera decedents, correctly concluding that the bacillus, which he named *Vibrio*, was cholera's likely causal agent [12]. But his work, like Snow's, was ignored [13]. The *miasma* theory was simply too set in public and scientific imagination for any other option, no matter how empirically supported, to be given credence [14]. When a Board of Health Committee for Scientific Inquiries identified a high concentration of cholera deaths near the Broad Street Pump, its 1855 report nonetheless concluded that *miasma*, not "choleraic excrements," had caused the excess deaths, "simply in the fact of [the pump's] impure waters having participated in the atmospheric infection of the district" [15,p. 52).

That biological evidence of the "cholera poison" was so summarily dismissed was remarkable because evidentiary support for *miasma* theory consisted of little more than folklore; normal human revulsion to foul odors; and misguided, albeit careful, scientific investigations, including meteorological observations of cholera clouds, microscopic examination of airborne particles thought to compose the clouds, and a simple cross-sectional inverse association of elevation above the Thames with cholera mortality rates [8,13–15]. Yet, in an editorial published shortly after Snow's testimony, the *Lancet* editors contrasted his "crude opinions and hobbyistic dogmas" with the "comprehensive and well-weighed decisions" of the "true representatives" of science [7,p. 634].

This contrast of Snow's "hobby" with true science was also remarkable. By 1855, Snow had produced more than 50 published articles encompassing an impressive array of scientific techniques and topics: quantitative experimental studies of the displacement of oxygen by carbon dioxide in asphyxia; case studies and guidance on chloroform anesthesia; and detailed epidemiological analysis of urban versus rural mortality, for example [13]. By any objective assessment, Snow's techniques, including careful measurement and empirical analysis, clearly met the definition of post-Enlightenment scientific inquiry [16,17]. So established was his scientific reputation that he was called upon in 1853 to attend Queen Victoria in childbirth [13]. Yet, once he publicly questioned the application of *miasma* theory to public health policy, he quickly became, according to *The Lancet* editors, an enemy of the "free progress of science" [7,p. 534].

Arguably given this history, Snow's work should have been viewed not as the *absence* of science, but as *competing* science, developed by a recognized master of the craft. In this sense, *The Lancet* editors' assessment represented a fundamental error in the core task of scientific epistemology: defining the criteria by which legitimate knowledge may be distinguished from unfounded opinion [18]. Why did this error occur?

### *Epistemology, scientific revolution, and paradigm*

The history of "obstinate belief" in *miasma* despite substantial evidence to the contrary [14,p. 1469] likely comes as no surprise to readers of Kuhn's book, *The Structure of Scientific Revolutions* [5]. Kuhn describes a cyclical process of epistemological development in which paradigms, conceptual frameworks that serve as a sort of lens through which the entire scientific enterprise is viewed, profoundly influence study design, data collection, and interpretation. Such paradigms, which define what valid science is and how to conduct it, are typically replaced only upon overwhelming evidence of their error, after which those clinging to older paradigms are gradually marginalized and ignored.

The power of paradigm was evident in the data-collection protocol provided by Hall to inspectors sent to investigate environmental conditions on Broad Street in 1854 [13]. Despite evidence published by Snow in 1849, carefully tracing the path of sewage from the homes of cholera-infected persons to the water supplies of households whose residents subsequently became ill with the disease [3,19], only 2 of about 50 instructions addressed Snow's theory at all, and neither included comparative analysis of cholera incidence by water source [13]. Predictably given the protocol, which focused predominantly on atmospheric and meteorological conditions, the investigators found "no reason to adopt" Snow's position [15,p. 52]. No public health action to remove human waste from the water supply was taken until 1858, when a summer heatwave produced intense stench, dubbed the "Great Stink" by the press, without resulting in the expected overwhelming volume of new cholera cases [14]. With that event, the tide of opinion began to turn, a modern sewage system was launched in 1858, and

the *miasma* theory was refuted by public health officials in 1866 [13,14].

Two important points should be noted. First is the fundamental role of anomaly in scientific revolution [20]. Defined by Kuhn as "nature's failure to confirm entirely to expectation," anomaly prompts further research and, if implications of the findings are sufficiently "deep" and "far-reaching," paradigmatic shift [20,pp. 762, 764]. The "Great Stink" event was far from the first anomaly in the 19th-century history of cholera. Snow's extensive investigations were permeated with recognition of profound anomaly between *miasma* theory and empirical observation. For example, the first argument he made in his 1849 treatise on the "mode of communication of cholera" was a point of basic logic [3,p. 6]:

> … it is difficult to imagine that there can be such a difference in the predisposition to be affected or not by an inhaled poison, as would enable a great number to breathe it without injury in a pretty concentrated form … whilst others should be killed by it when millions of times diluted.

Similarly, in comparing two closely proximate courtyards presumably experiencing the same atmospheric *miasma*, Snow noted that one, where "cholera has committed fearful devastation," differed from another, where only two cases had been identified, in only one respect: "the well from which they obtained their water" [3,p. 13].

Second is the often-lengthy process of scientific revolution. Neither the 1858 "Great Stink" nor the 1866 refutation of *miasma* theory fully ended *miasma* adherence. For example, James Glaisher, a renowned meteorologist, wrote a letter to *The Times* in August 1866, warning in strong terms of an impending epidemic signaled by blue mist [9]. His letter was quickly followed by a flood of responses to *The Times*, as well as accounts of similar instances published in *The Lancet*, the Philadelphia *Medical and Surgical Reporter*, and other medical journals [9].

Even at the end of the 19th century, reports of cholera clouds appeared frequently in the medical literature and popular press, sometimes accompanied by explanations of the biology underlying their effects [9]. One historian later described these reports as attempts "to reformat the cholera cloud to bring it in line with emergent scientific understandings" [9,p. 317]. As late as 1911, a letter to *The Lancet* referred to a "cholera cloud on the continent," the author's term for disease resurgence that had occurred despite policies of the "water fanatics" [21,p. 471].

This pattern is consistent with Kuhn's suggestion of a transition period, often lengthy, from one paradigm to another. Scientific revolutions, and the "extended struggle with anomaly" that precedes them, are not single events, Kuhn emphasized, but complex processes [20,p. 763] that typically end only with the death of adherents to the old paradigm [5].

### *Biomedical specialization as an emerging 20th-Century paradigm*

The import of the events of 1855 for scientific paradigm is revealed in the backgrounds of the principals. William Farr, a longtime *miasmist* described in the *Lancet* editorial as the "only thoroughly scientific witness" to Parliament [7,p. 635], had trained as a doctor and practiced briefly as a house physician, but had since devoted his work to developing a national vital statistics system [22]. Board of Health leader Edwin Chadwick, who had spearheaded an ill-conceived public works project to remove *miasma* from London by dumping thousands of tons of human waste into the Thames River in the 1840s [13,14], was a social reformer with a passion for the well-being of the poor and no medical training [23]. James Wakley, the primary *Lancet* editor at the time of Snow's testimony, had studied medicine but never practiced it [24].

In contrast, as an anesthesiologist, Snow understood, better than anyone else involved in the debate at the time, the physical properties and physiological effects of gaseous material [19], to which he referred frequently in his 1855 testimony [1,2]. In evaluating what *miasma* could (and could not) do, Snow had something none of his opponents had: specialized biomedical expertise. Moreover, although 19th-century physicians recognized the possibility of person-to-person contagion in some diseases, cholera generally not among them [25], Snow's "cholera poison" introduced a new, uniquely biomedical element to the debate, although he did not recognize it at the time: a singular, molecularized explanation for disease [16].

Viewed in this context, governmental movements toward Snow's position represented the first glimpse of a new era in the evidentiary foundations of health policy: from general knowledge to biomedical specialization. With further confirmation of *Vibrio cholera* in the work of Robert Koch and similar discoveries about rabies, anthrax, tuberculosis, and diphtheria at the end of the 19th century, the benefits of biomedical expertise began to capture public attention [26]. Biomedicine, which had competed with other medical disciplines for political influence since the 1830s, had won out [18,26].

In the early 20th century, reliance on what medical education reformer Abraham Flexner described in 1915 as "definite sciences—anatomy, physiology, pharmacology, etc." [27, para. 10] became the goal of medical schools and an increasingly powerful American Medical Association [18,28]. By the 1920s, the image of physicians as the experts uniquely qualified to evaluate, treat, and provide counsel on human ailments was firmly established in the American psyche [26,29]. A move away from earlier, more metaphysical explanations of disease, toward increasingly physiological and reductionist approaches, became evident. For example, a historical account of the National Institutes of Health Clinical Center observed that the institution, founded in 1953 as a "bench to bedside and back … jewel in the medical universe" with "state-of-the-art hospital beds married to world-class research facilities and world-class scientists," provided unique scientific opportunities because "the only patients we bring into this hospital are patients who can help us answer questions" [30, cover, p. 16].

American public health reflected these changes. Key 20th-century policy developments, including the Kefauver-Harris Amendment to the Food and Drug Act in 1962, which required that controlled trials support new drug applications, and the combination of chemotherapeutic developments and screening programs in the "war on cancer," represented newly formed alliances between public health and biomedical science [31,p. 450]. A 1983 commentary by Lewis Thomas, an influential physician and nature writer, suggested that the future of public health lay in "basic science at its best," such as the cellular production of monoclonal antibodies, rapidly growing understanding of oncogenes and viral genomics, and research technologies that were "powerful and precise" [32,pp. 37, 38].

Mirroring these trends, American medicine became increasingly specialized and subspecialized throughout the 20th century [26,33]. In 1920, nearly all physicians were general practitioners providing primary care, a figure that declined to 76% in 1940, 50% in 1961, and 33% in 2015 [33]. The resulting ever-growing emphasis on biomedical expertise paved the way for reliance on infectious disease physicians in COVID-19 policy development.

### *Competing scientific paradigms in the COVID-19 era*

In 2020, as in the 19th century, the backgrounds of the principal decision makers revealed the dominant paradigm. Although the White House Coronavirus Task Force that promulgated federal stay-at-home (i.e. "lockdown") guidance in March 2020 included

business executives, attorneys, and an anesthesiologist, the three primary decision makers were infectious disease physicians who had spent decades fighting epidemics, including human immunodeficiency virus [34].

Which health-related disciplines were *not* represented? The Task Force included no experts in behavioral sciences or education, despite the effects of its decisions on mental health service delivery, substance use disorder treatment, and schools and universities [35–37]; none in decision analytic modeling, despite the influence of nonpeer-reviewed models using controversial methods on governmental decisions [38–40]; none in risk communication, despite a recognized need to explain public health risks and risk-mitigation policies effectively, using known best practices derived from psychological science [41]; and none in health informatics, despite known inaccuracies and coding biases in the cause-of-death data on which the Task Force relied [42–44].

These omissions were not anomaly; arguably, they reflected the ongoing dominance of biomedicine in U.S. federal public health. For example, although behavioral health falls within the scope of many health agencies [32,45], a 2015 commentary on the most important challenges and opportunities facing public health, written by then-Director of the U.S. Centers for Disease Control and Prevention (CDC) and infectious disease physician Thomas Frieden, made no mention of mental or substance use disorders, including overdose [46]. Similarly, biomedical expertise remains predominant on current leadership teams of both the CDC and the COVID-19 Task Force [47–50]. Top CDC clinical leadership, including the Deputy Director for Public Health Science and Surveillance, includes four infectious disease specialists, one injury prevention specialist, and no psychologists or psychiatrists [47]. Current COVID-19 Task Force members include a physician specialist in social determinants of health (SDOH) and the Surgeon General, who brought the U.S. opioid crisis to the attention of the nation's physicians for the first time in 2016, but no specialists in psychiatric disorders, substance use disorders, or education [48–50]. Its public-facing decision-making and communications processes are performed by two infectious disease specialists [48,49].

One might, therefore, reasonably contrast the scope of impact of federal pandemic-period decisions, such as on education and behavioral health, and the predominantly biomedical background of the decision makers. This contrast was echoed in disputes described as "COVID science wars" and expressed in competing public statements in October 2020 [51]. Posted first, the "Great Barrington Declaration" acknowledged the risks COVID-19 posed to the "old and infirm," but highlighted harms, such as mental health deterioration and foregone preventive care, resulting from stay-at-home orders and school closures [52,para. 4]. The Declaration argued for "focused protection" of those at highest risk, such as retirees and nursing home residents, while promoting "herd immunity" by allowing the virus to circulate among young and healthy persons [52,paras. 1,5].

Written in response, the "John Snow Memorandum" focused primarily on biomedical considerations of viral contagion and sequelae [53]. The Memorandum observed that persistent post-infection symptoms and mortality occur even in younger, healthier persons, that lack of "evidence for lasting protective immunity" after infection made the Barrington strategy "a dangerous fallacy," and that the catastrophic effects of COVID-19 illness made lockdowns and similar restrictions "essential" and other proposed approaches "distractions that undermine an effective response" [53,paras. 4, 6, 9].

As tempting, and common, as it is to characterize these debates as a battle of science on the Snow memorandum side versus political philosophy on the Barrington side [54], advocates for both positions include numerous distinguished public health scientists [51–53]. The true epistemic conflict is deeper and more important.

*Biomedicine versus holism*

Hallmark tenets of a biomedical paradigm—expert knowledge of and dominion over nature, view of health as absence of physiological dysfunction, notion of "singular and specific" causal agents for disease, and molecular reductionism—may be contrasted with a broader, holistic view of health as encompassing not only physiological but also psychosocial and socioeconomic well-being [16,p. 145]. Previous research has suggested complex relationships among subcategories of well-being encompassed in holism, including psychosocial health and SDOH [55,56]. Accordingly, medical practice has begun to move away from purely biomedical models and toward incorporation of psychosocial and socioeconomic considerations, both in chronic disease treatment protocols [57,58] and in medical education [59].

For example, treatment guidelines for diabetes and chronic kidney disease recommend multidisciplinary team-based care incorporating expertise in mental health, physical rehabilitation, nutrition, and other services to help patients and families manage psychological distress, complex treatment regimens, and comorbidities [57,58]. Both guidelines recommend assessments for social well-being, and the diabetes guideline recommends assessment of SDOH (e.g. food security, housing, health literacy). Similarly, the medical education literature reflects increasing efforts to teach future physicians about psychosocial problems and SDOH [59].

The contrast between biomedicine and holism provides a helpful framework for understanding the Barrington/Snow memorandum debate. On the biomedical side, viewed from the specialized infectious disease focus on contagion, it is easy to understand the statement of the lead Task Force physician in mid-March 2020 that public perceptions of governmental overreaction to COVID-19 were a good sign that "we're doing it just right" [60,para. 2]. Yet, manifesting a more holistic view, observers at the time raised concern about the uncertain benefits of the government's historically unusual and largely untested population-wide strategy of confining persons with unknown disease exposure status to home [61–63] in light of potentially harmful exacerbations of already recognized health problems, including suicide, substance use disorders, and economic deprivation [63–65].

Reflecting this debate in comments made in November 2020, psychiatrist Elinor McCance-Katz, whose absence from the Task Force is noteworthy given her position as national head of the Substance Abuse and Mental Health Services Administration, characterized emerging evidence of pandemic-period increases in suicidality and overdose [66,67] as the result of a failure to recognize behavioral health as a legitimate public health issue [68,paras. 4, 5]:

> Before we even knew about this pandemic, we had over 180,000 Americans every year that die of suicide, of drug overdoses, and of alcohol related problems.... Those numbers are going to go up because of the restrictive measures that have been taken. … And we continue to hear people who are called public health experts tell us that it should remain that way. I would argue that a public health expert needs to consider all aspects of health. I will tell you mental and substance use disorders are public health issues, just like COVID.

These remarks suggest the import of the COVID-19 "wars" may extend far beyond disagreement over optimal virus-mitigation strategy, reflecting instead an "epistemic contest" [18,p. 491] over the foundations of contemporary public health science and practice. Important questions about shared understandings of health and, by extension, health expertise, are suggested by the contrast between the growing holism in medical practice and the reliance on biomedicine in federal pandemic-policy development. If health is increasingly understood to be inherently holistic, and there-

fore multidisciplinary by its very nature, should the public health decision-making process, and the science undergirding that process, not be multidisciplinary as well? If epidemiological science, the cornerstone of public health, encompasses research into multiple causes and types of disease, as is commonly understood [69], why has most scientific influence on U.S. federal pandemic policy been concentrated in the hands of a single medical subspecialty?

The answer to these questions may be that a process of paradigmatic shift in American understandings of health and health expertise is currently reflected to a greater extent in medical than in federal public health practice, with the exception of attention to SDOH in both fields [55–59,70]. If so, the question of how this paradigm shift might alter the effectiveness of public health response to crisis becomes important.

### *Expediency versus evidence?*

The Snow memorandum's characterization of Barrington concerns as "distractions" [53] raises an important question: in a public health emergency, should decision makers rely primarily on familiar paradigms rather than potentially wasting precious time on considering evidence of less certain benefit? Interestingly, this question of expedience versus evidence is not new; it was raised in 1855 by the Board of Health Committee for Scientific Inquiries, which asked Hall for "indulgence for much that is imperfect in our work" because "it would be vain to expect that observations begun in the crisis of an epidemic should have that completeness which science requires, and which only deliberate preparation can ensure" [15,p. 5].

Here, too, a 19th-century event, massive pollution of the Thames by a sewage system intended to remove *miasma* from London's streets in the 1840s [13], may provide a lesson for contemporary decision makers: the risk of unintended harms from policies with an uncertain evidentiary basis. Even the firmly *miasmist* Medical Council in 1855 described the sewage system, despite its "sanitary advantage," as having "indirectly led to another evil," the "abominable filth" found "in the drinking-water supplied to a large part of the population" [8,p. 6–7]. With the benefit of knowledge not available to the 1855 Council, that the "filth" carried *Vibrio cholera*, one analyst observed ironically in 2006 that this "first, defining act of a modern, centralized public-health authority was to poison an entire urban population." [13,p. 120].

Henry Whitehead, a local clergyman and initially a *miasmist*, who nonetheless facilitated Snow's research out of their mutual desire to identify cholera's cause, may have gleaned from Snow's work a sense of the need for circumspection in policy development. According to the corrected *Lancet* obituary, Whitehead kept a portrait of Snow on his wall after the physician's untimely death in 1858 to remind him, he said, that "the highest order of work is achieved not by fussy demand for 'something to be done,' but by patient study of the eternal laws." [6,p. 1270].

The difficult question of exactly how "patient" such study should be is outside the scope of the questions of paradigm considered here. However, the possibility of paradigm shift suggests how the evidentiary process for this and future pandemics might be modified to afford the necessary degree of circumspection without sacrificing expedient response, and perhaps even enhancing it: apply to public health science the multidisciplinary approach already being incorporated in medical care and education.

### *Fulfilling the vision of evidence-based practice: toward a new paradigm of multidisciplinary engagement in public health policy formation and evaluation*

The inconsistency between contemporary holistic understandings of health [28,55–59] and the process used to develop U.S. COVID-19 policy suggests a need for a modified epistemology that recognizes the effects population-level public health decisions inevitably have on multiple aspects of health: physiological, psychological, behavioral, and social. Such decisions are inherently multidisciplinary, regardless of whether their proponents acknowledge them as such, and are best served by the application of multidisciplinary expertise to policy development and evaluation. This proposed epistemological shift from biomedicine to holism in American public health science, although conceptually similar to methodological changes that commonly follow in the wake of pandemics [71], would have potentially broader implications for the policy research paradigm by affecting scope, method, and shared understandings of health expertise.

For example, in translational epidemiological research to inform policy for future public health crises where U.S. population-level interventions are considered, this change might take the form of quantitative evaluation of the association of COVID-19 policy interventions with morbidity and mortality, assessing not only reductions from avoided infection [72], but also increases from potential unintended consequences, such as unemployment-related economic deprivation, delayed medical care, domestic violence, social isolation, and psychological distress [63–65]. The lack of high-quality, comparative evidence to guide nondrug pandemic-mitigation policy decisions, such as school closures or physical distancing, has been described elsewhere [73,74]. This evidentiary gap represents an important discordance between current epidemiological scholarship and the core activity of evidence-based medicine, quantitative assessment of both benefits and harms of measures to prevent and treat disease [75]. A modified epistemology that recognizes the importance of measuring all aspects of health would point clearly to this gap in the scientific literature.

The epistemological shift would also affect the choice of principals to conduct this research and interpret its findings. The possibility of severe COVID-19 illness and the problems of long-term sequelae and uncertainty about the virus [76–78] suggest infectious disease specialists should continue to play a prominent role. However, evidence of lockdown- and pandemic-associated deterioration in mental health, particularly of children, adolescents, and young adults [66,67,79–81], suggests a need to involve behavioral health and educational specialists as well. Informatics and modeling specialists are needed to assess the source data and assumptions used in epidemiological analyses, consistent with calls for quality improvement in cause-of-death attribution for respiratory illness-related mortality [42,44]. Finally, evidence of disproportionate lockdown- and COVID-19-related impact on vulnerable populations suggests a need for measurement and characterization of these effects by scientists with expertise in SDOH [82,83]. Identifying optimal methods for measuring and interpreting these outcomes requires input from experts in their respective fields.

## Conclusion

A few years ago, a student asked me a good question after a class session on John Snow: "What is our *miasma*?" What, the student wondered, is the "obstinate belief" on which scientists will look back in 100 years and say: "What were they *thinking*?" Doubtless, those on both sides of the COVID-19 "wars" believe this true of the opposing side. Yet, despite its moniker, which implies scorned views that ultimately achieved dominance because of evidentiary superiority and related cultural changes, the John Snow memorandum currently represents dominant science [51], grounded in a biomedical paradigm. The question of whether evidence will ultimately support that dominant view is currently unanswered and merits careful epidemiological study.

As important as this research is, prognostication about its eventual result may be less consequential than recognition of the epis-

temological shift required to conduct it well. Inconsistency between the primarily biomedical foundation of much population-level public health policy and its inherently broad social impact may represent a currently unrecognized 21st-century "obstinate belief" that merits reconsideration, potentially having profound effects on American epidemiological scientific practice. Measurement of health outcomes from a single perspective—be it biomedical, psychological, or social—risks the loss of the added insights that could come from a more holistic approach.

With a new paradigm of reliance on expertise in multiple health-related disciplines as a scientific framework, the public health research process would address physiological, psychological, behavioral, and social health when assessing population-level policy decisions, engaging experts from these respective fields in study design, execution, and interpretation. Each discipline would bring to the table its expertise in topic selection, study design, empirical measurement, and interpretation. Each would bring the efficiencies that come with highly advanced knowledge in their respective fields. Each would bring unique insights into how to implement, and monitor the effectiveness of, policy ideas advanced by the others. Only with this shift can public health science ask the right questions, use optimal methods, and engage in the robust dialogue necessary to follow wherever the evidence leads.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.annepidem.2022.02.005.

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