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Review Article

Bridging the epidemiology-policy divide: A consequential and evidence-based framework to optimize population health

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ABSTRACT

Epidemiology is the scientific cornerstone of public health. Its traditional role has been to test scientific hypotheses on causal relationships of exposures with health outcomes, the results of which should in turn be synthesized and lead to evidence-based recommendations and the formation of policy. However, the messy truth is that the path from epidemiology to policy is frequently not a perfectly rational, linear one, and the choices of which scientific hypotheses are pursued and the ways in which they are tested, evaluated, and translated into policies do not occur systematically. One avenue for bridging this divide is widespread adoption and implementation of a consequential, evidence-based framework—whereby we can systematically facilitate the translation of epidemiology into policies and interventions to optimize population health. This paper describes the roadmap for a seven-step, outcomes-based consequential approach, that includes priority-setting of problems at both the federal and regional/state levels, and that proposes to strengthen alignment of public and private research funding and journals with these priorities. Over the long term, implementing this framework should help to bridge the divide between epidemiology and policy and optimize the use of increasingly constrained resources to reduce disease burden and promote the nation's health.

1. Introduction: need for a consequential, evidence-based epidemiology

Epidemiology is the scientific cornerstone of public health. Traditionally, its role has been to test scientific hypotheses on causal relationships of exposures with health outcomes, the results of which contribute to a body of knowledge. In turn, this knowledge is synthesized through systematic reviews, meta-analyses, and economic evaluations, and should lead to evidence-based recommendations and the formation of policy (Fig. 1) (Samet, 2000). The messy truth, however, is that the path from epidemiology to policy is frequently not a perfectly rational, linear one (Exworthy, 2008). Furthermore, the choices of which scientific hypotheses are pursued and the ways in which they are tested, translated into policies, and evaluated do not occur systematically. Absent an overarching evidence-based framework with guidelines and incentives, research efforts by epidemiologists to improve population health and reduce health disparities may be inefficient. This problem is magnified by ever-tightening fiscal constraints in an age of spiraling federal debt and austerity.

Increasingly, epidemiologists have called for an epidemiology that is more 'consequential' in nature—an epidemiology more directly linked to interventions or policies to address public health issues of concern (Galea, 2013), revitalizing earlier calls for this paradigm shift (Foege, 1983).

Consensus is growing that assessing the impacts of large-scale policies is very much in the purview of epidemiology (Nandi and Harper, 2015). Several epidemiologists have criticized the discipline's lack of evaluation of macro-level policies and programs to inform evidence-based solutions to the complex problems that generate and perpetuate health inequalities (Nandi and Harper, 2015; Muntaner, 2013; Galea and Link, 2013; O'Campo, 2012). Moreover, these gaps extend beyond the traditional walls of epidemiology. For example, in the U.S., there is sparse evidence on the effectiveness of social policies: One report found that of 10 large-scale federal social programs evaluated for their effectiveness between 1990 and 2010, nine programs had little to no effect (Haskins and Baron, n.d.). In addition, a review of scientific abstracts presented at annual meetings of the U.S. Society for Epidemiologic Research from 2009 to 2013 determined that only a relatively small fraction (6.6%) of research on the social determinants of health was consequential (Nandi and Harper, 2015).

Overall, the public health literature and recent academic discourse hence point to a significant divide between epidemiology and policy. One avenue for bridging this divide is widespread adoption of an outcomes- and evidence-based framework—through which we can systematically facilitate the translation of epidemiology into policies and

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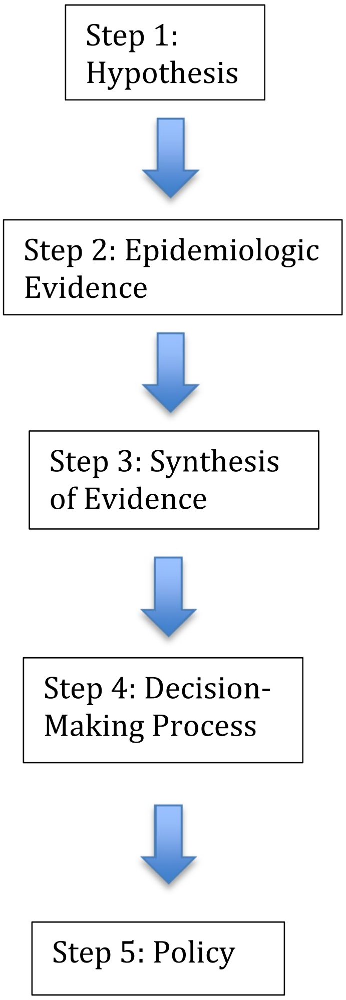

Fig. 1. The traditional conceptual linkage between epidemiology and policy. (Adapted from Samet (2000)).

interventions to optimize population health.

1.1. *Key elements lacking in current epidemiology-policy frameworks*

Several key elements are lacking in existing frameworks that draw conceptual linkages from epidemiology to policy and indicate the need for a new overarching framework:

1. Comprehensive summaries of existing knowledge and knowledge gaps in life expectancy, morbidity and mortality, disability-adjusted life-years (DALYs), cause-specific mortality and morbidity, risk factors, and preventable burden and economic costs and benefits associated with interventions and policies that address the social determinants of health. The U.S. Community Preventive Services Task Force (CPSTF) has also only reported on a limited number of social determinants of health to date. For example, for cardiovascular disease (CVD) prevention, of 10 reviewed interventions (Community Preventive Services Task Force, n.d.), none directly address social determinants of health.
2. Grant funding agencies' explicit prioritization of research on the social determinants of health and studies of direct policy relevance and their indication of targeted levels of support for such research. Currently, the social determinants of health are emphasized inconsistently across strategic plans of the U.S. National Institutes of Health (NIH) (National Institutes of Health, n.d.-a), and their targeted funding levels are inapparent. Meanwhile, there appears to be a substantial underinvestment in such areas (see section entitled '*Suggested Underinvestments of NIH Funding*').
3. The use of alternative metrics to measure the impacts of scientific research papers on policy. If such metrics could be adapted to capture engagement by policymakers, this would be a step forward towards measuring policy-related influences of research.
4. Improvements by public health journals of structured information regarding the significance of articles e.g., relevance to burden of disease. Making such information available to peer reviewers would strengthen their ability to evaluate the policy relevance of manuscripts and incentivize researchers to pursue topics of greater significance.
5. Considerations of the roles of academic institutions and the sociodemographic characteristics of epidemiologists and barriers faced in the academic world to influence the conduct of consequential epidemiologic research.

The epidemiologist Nancy Krieger has called attention to the roles in shaping population health that institutions and individuals play in acting ("agency") and taking responsibility ("accountability"), for actions both taken and avoided (Krieger, 2011). As applied to influencing the burden of disease, one can conceive of institutional barriers and sociodemographic characteristics of epidemiologists (e.g., race/ethnicity, gender) interacting with these barriers to affect the conduct of policy-relevant epidemiologic research (Kietzman et al., 2016). Qualitative research supports the existence of such barriers including the following:

1. Tenure and promotion place great emphasis on peer-reviewed articles published in journals according to conventional indicators such as the journal impact factor (Hovland, 2007). However, policy development and implementation typically take several years, and the short-term impacts of research in the policy sphere are insufficiently captured using standard metrics (Kietzman et al., 2016).
2. The research agenda undertaken to inform public policy is often viewed as tangential and risky for early-career faculty by those making tenure and promotion decisions (Kietzman et al., 2016; Green, 2008).
3. Among minority faculty and women, the above two issues compound a perceived lack of support for the tenure/promotion process and exacerbate the contributions of institutional barriers to racial/ethnic and gender disparities in being promoted and achieving tenure (Kietzman et al., 2016; Fang et al., 2000; Nunez-Smith et al., 2012).
4. Few epidemiology training programs provide an adequate foundation for investigators to ask policy-relevant research questions and apply experimental or quasi-experimental methods to evaluate interventions.

Each of these barriers has corresponding solutions, that would most likely be enhanced by formal recommendations from public health and epidemiology bodies such as the U.S. Association of Schools and Programs of Public Health (ASPPH) and Society for Epidemiologic Research (SER) and the International Epidemiological Association (IEA).

2. Elements of a consequential approach

What should form the basic elements of an outcomes-based/consequential approach? Preliminary steps should include characterizing the extent of existing public health problems at multiple geographic levels, and setting priorities based on various criteria including disease burden and equity considerations. Evidence-based guidelines and evidence on the effectiveness of scaled-up policies to address these problems should also feed into the priority-setting process, thus turning the conventional direction of epidemiology to policy formulation on its head. Moreover, the setting of priorities should drive the allocation of research funding, conduct and evaluation of evidence-based interventions, and formulation of policies to promote population health. Hence, this consequential approach would consist of a series of steps that begins with priority-setting, integrates policy considerations, and stimulates synthesis of a body of policy-relevant evidence. Notably, these steps would not simply be sequential, and would also incorporate reciprocal feedback loops. In the remainder of this paper, I detail a roadmap for a seven-step outcomes-based/consequential approach.

Step 1: Characterizing the Burden of Disease and Health Disparities

As proposed by Fielding and Teutsch (2013) to document aspects of the significance of conducted research, *Step 1* would integrate descriptive statistics to establish the burden of disease, characterize health disparities, and identify emerging threats (e.g., opioid misuse/suicide trends). In the U.S., this burden of disease would be measured for mortality and morbidity (disease incidence, DALYs, and quality-adjusted life-years [QALYs]) (The Global Burden of Disease 2015 Collaboration, 2016) at the federal, state, county, city, and neighborhood levels. The disease burden could plausibly interact with factors such as gender, race/ethnicity, socioeconomic status, and geography, and thereby shape health disparities along these axes. By characterizing such health disparities, we can better prioritize interventions and policies to maximize population health equity.

Notably, there still exist key knowledge gaps in current assessments of the U.S. burden of disease. For example, a 2017 Institute for Health Metrics and Evaluation (IHME) study published the first county-level age-specific metrics of survival (Dwyer-Lindgren et al., 2017). Similar assessments of life expectancy and age-specific mortality are lacking at other local levels. Likewise, IHME analyses have yet to explore cause-specific mortality at the U.S. county level and investigate heterogeneity of spatial inequalities along axes such as gender and socioeconomic status (Clark and Williams, 2016).

The *preventable burden* at multiple spatial levels is also in need of greater assessment. A 2005 systematic review found that preventable fractions, which serve as indicators for intervention effectiveness, were provided for only 4.4% of public health interventions (Thacker et al., 2005). Yet an updated systematic review has not been published since—representing a key evidence gap reflecting our lack of knowledge of the status of applications of this policy-relevant metric within public health. Notably, some behaviors are more modifiable than others. In turn, even among modifiable behaviors, interventions may be more effective for some of these behaviors than others. Information on preventable fractions can be valuable in identifying the most promising solutions and the places where resources can be most efficiently allocated.

In addition, the *economic burden* at multiple geographic levels should be evaluated. In the face of budgetary constraints, economic evaluations can critically inform policymakers' decision-making by helping to quantify a policy or program's impact and its estimated costs and benefits if scaled up (Rabarison et al., 2015). To date, however, few studies have explored the economic benefits of intervening on the social determinants of health (McDaid and Needle, 2007).

Step 2: Setting Priorities at the Federal and State/Regional Levels

In this second step, due to resource constraints, priorities would be set at the federal and state/regional levels based on multiple factors, including available data on preventable burden and economic burden (*Step 1*), evidence-based guidelines for scaled-up interventions and policies (*Step 6*), and subsequent evidence on scaled-up intervention/policies (*Step 7*). Because political will varies by region, discrepancies may exist between the priorities set at the federal and regional levels (Teutsch and Fielding, 2011); priority-setting at both levels is hence essential. A wide variety of methods have been developed for the priority-setting process, including the preference survey method, simplex method, and Hanlon method (Spasoff, 1999; National Association of County and City Health Officials, n.d.). Because the burden of disease and health disparities, preventable burden, and economic burden in *Step 1* have still not been well characterized, significant improvements are needed in the priority-setting process. Although priority-setting processes may vary by method and geography, where possible, relatively greater amounts of weight/consideration should be given to the estimated preventable burden and economic burden.

Step 3a: Priority-Setting by Grant Funding Agencies

Grant funding agencies and public health and clinical journals provide key incentives for the types of epidemiologic research conducted. They can thereby play pivotal roles in strengthening linkages along the epidemiology-policy continuum. In *Step 3a*, public funding agencies would allocate funding based on results of the priority-setting process and prioritize funding for selected topics and methods e.g., studies on social determinants of health and of direct policy relevance, and studies that apply more causally-robust designs. Ideally, coordination of public funding would occur at the federal level, with additional input from state/regional governments. A comprehensive inventory of recent funding awarded by private research funding agencies and foundations would further help to identify funding gaps. Public and private funding agencies should also share details of their funding priorities to ensure greater alignment.

At the same time, evidence suggests that public research funding on health has largely not been driven by the burden of disease. For example, studies analyzing public data on NIH funding for the most common conditions have found that the total burden of disease as measured by DALYs accounts for only 26–33% of the variation in funding levels (Gillum et al., 2011; Moses et al., 2015). Similar concerns and evidence about the skewed distribution of national research funding have been echoed in other countries including the U.K., Canada, and Australia (The Academy of Medical Sciences, 2016; Aoun et al., 2004). The U.S. Congress has previously raised concerns that disease-specific funding allocations by the NIH have failed to adequately reflect the burden of disease and incorporate public input (Institute of Medicine (US) Committee on the NIH Research Priority-Setting Process, 1998). 27 diseases that accounted for 84% of mortality and 70% of DALYs in 2010 received 48% of NIH funding ($r^2 = 0.26$). In 2008, the NIH created the Research, Condition, and Disease Categorization (RCDC) system to provide a standardized methodology for classifying funds by disease area. According to this new classification system, mortality explained just over half (54%) of the variation in funding (Sampat et al., 2013).

There are political, economic and institutional reasons why current research priorities do not match the distribution of the burden of disease. For example, outside lobbying from special interest groups (such as patient/illness groups and industry representatives) may influence financial allocations by Congress to various NIH institutes (Hanna, 2015). A mixed methods study of 15 diseases found that for each $1000 spent on lobbying for a single disease, there was an increase of $25,000 in NIH funding for that disease in the subsequent year (Hanna, 2015; Best, 2012). The media also likely influences the perceptions of Congress and the public about the importance of specific diseases, that may not correspond with actual burden (Hanna, 2015). To minimize such influences, mechanisms should be in place to ensure taxpayer funding for research reflects objective health needs, without being distorted by lobbying efforts or media campaigns (Hanna, 2015). The NIH should further seek public and expert input, including providing fair hearings to funding allocations that lack the support of powerful interest groups.

Furthermore, priority-setting occurs in a profoundly political context (Hauck et al., 2016). Hauck and Smith (2015) have proposed several key aspects of political forces/economy to help explain how priority-setting decisions may be influenced by how policymakers react to political realities: the median voter model, interest groups, bureaucratic decision-making, decentralization, and equity. Political science theories of the policymaking process have been used to reveal that driving forces for the inclusion of social determinants of health initiatives in government policy agendas include the framing of the social determinants of health in public, media, and political discourse; institutional norms; mobilization of civil society; and the election of social-democratic governments (Baker et al., 2018). Overall, there may be substantial benefits to using theories and models based on political economy to better understand the complex processes of priority-setting (Goddard et al., 2006).

Step 3b: Priority-Setting by Scientific Journals

Most public health journals are private and not public entities. Nonetheless, public health journals have the capacity to reset their priorities for the scope of topics and methods published, including an emphasis on studies of greater public health consequence such as those with inherently stronger internal validity (e.g., RCTs, natural experiments), modifiable exposures with high population attributable risks (PAR), studies that address the social determinants of health, research based on economic evaluations or comparative effectiveness, and intervention studies that report preventable fractions (PF) (Thacker et al., 2005). For example, two journals, the *Annals of Epidemiology* and the *American Journal of Public Health*, now regularly feature research articles of consequence (Davis et al., 2012; Galea and Vaughan, 2016).

The International Committee of Medical Journal Editors (ICMJE) could play a pivotal role in influencing journal content priorities, such as by making recommendations for a minimum level of content in general medical and public health journals on selected topics such as the social determinants of health. Because compliance with ICMJE recommendations is required for most leading biomedical journals, and over 3000 journals follow ICMJE requirements, the impact could be demonstrable. An annual inventory of the distribution of content in journals, made available to the public and public health associations, could help raise awareness and transparency about journal priorities and deficiencies, and nudge journals to better align their content with federal and state priorities.

In addition, as recommended by Fielding and Teutsch (2013), public health journals should improve the structured information (e.g., relevance to burden of disease, preventable burden) to enable journal reviewers and editors to better identify the significance of submitted research. Fielding and Teutsch (2013) have suggested that journal editors, such as under the auspices of the ICMJE, convene an expert panel to formalize the types of information that each manuscript should contain, analogous to statements on reporting of clinical trials (CONSORT) and observational studies (STROBE).

As well, impact factors of academic journals are commonly used to reflect journal importance, and have implications for attracting paper submissions. Yet even a journal of high impact containing articles of higher internal validity or currency may not necessarily signify stronger policy contributions or greater interest by policymakers.

In recent years, article-level metrics or alternative metrics (Dinsmore et al., 2014) such as provided by PlumX and Altmetric that measure views, downloads, and citations in non-academic communications like social media, policy documents, and other efforts to translate research findings for general audiences such as op-eds, have emerged as tools to overcome limitations of conventional journal impact factors (Kwok, 2013). For instance, shortly after publication, an alcohol policy paper funded by the Wellcome Trust was discussed over social media at a high rate by key influencers including members of the European Parliament; meanwhile, such attention was invisible to conventional bibliometrics (Dinsmore et al., 2014). Hence, social media activity may serve as a proxy for engagement in the policy sphere. In addition, alternative metrics can demonstrate the relevance and utility of sponsored research using taxpayer dollars, and show funders the uptake and diffusion of research in the pipeline to policy (Dinsmore et al., 2014; Galligan and Dyas-Correia, 2013). Like traditional metrics, alternative metrics can also possess disadvantages, such as selection bias and a lack of disaggregation of positive and negative comments on the research in the case of social media (Bornmann, 2014). Further work is needed to validate process measures for policy-related impacts. Such metrics could additionally be used to consider the feasibility of scaling up the policy/intervention (*Step 6*), and as part of the evaluation of the policy/intervention when scaled up (*Step 7*).

There is evidence of progress being made in priority-setting by U.S. funding agencies. In 2016, the American Heart Association (AHA) published a policy statement on knowledge gaps such as in cardiovascular epidemiology to advance policy development for disease prevention (Labarthe et al., 2016). The AHA raised the importance of economic evaluations and called attention to the social determinants of health and vulnerable populations (Labarthe et al., 2016). Likewise, in 2013, the National Cancer Institute at the NIH published recommendations for transforming cancer epidemiology in the 21st century, with actions for consideration by funding agencies and the broader research community (Khoury et al., 2013). These recommendations included conducting meta-analyses to aid guideline development and policy, and ensuring that funding agencies have a more balanced epidemiologic portfolio including evidence-based guidelines, implementation strategies, and evaluation of interventions/policies (Khoury et al., 2013). Clear overlap exists in the recommendations that have emerged from the above and other agencies. Future efforts that catalogue and disseminate knowledge on the tapestry of research projects funded by various agencies would help to minimize inconsistencies and gaps in knowledge.

2.1. *Suggested underinvestments of NIH funding*

From a funding perspective, gaps may exist in supporting higher-priority topics and methods. To explore the degree of funding by NIH for primary research on the social determinants of health as well as evidence-based methods, I used NIH's RePORT Expenditures and Results Tool (RePORTER) (National Institutes of Health, n.d.-b) to identify key research funding (R01, R21, and R03) grants over a recent decade. Fig. 2 shows the allocation of funding dollars by year for the time period 2005–2015 based on grants using social determinants of health terms and grants with more rigorous or evidence-based methodological terms included in their project title (to maximize specificity). The specific search terms used are shown below the figure. From 2005 to 2010, NIH-based funding on the social determinants of health appears to have increased, from $56.6 million to $87.8 million. However, from 2010 to 2015, funding for these areas declined, from $87.8 million to $65.6 million i.e., returning to 2008 funding levels. For research on more robust/evidence-based methodological terms, there was an overall increase in NIH funding from 2005 ($31.1 million) to 2012 ($92.6 million). Funding has fluctuated since then, with evidence of declines ($73.8 million in 2013 and $86.2 million in 2015). Additionally, using RePORTER, I determined that NIH funding for both sets of terms combined only represents roughly 1% of all funding for these grant mechanisms in a given year (0.8% of $11.0 billion in 2005, 1.3% of $11.9 billion in 2015). Estimating funding levels using these title search terms might be limited by a lack of high sensitivity, and a more comprehensive analysis would be useful for benchmarking. Still, the true figure is most likely to be less than the 46% or greater proportion of mortality and morbidity attributed to social and economic factors (Park et al., 2015).

Overall, these patterns suggest a critical underinvestment in research on the social determinants of health and more methodologically rigorous, evidence-based research. In addition, the institutes that comprise the NIH are predominantly siloed according to disease area with separate budgets (Sharp and Langer, 2011). Research funding encompassing multiple sectors (e.g., blended funding, bringing multiple sources of funding together under a single budget) would help to streamline administrative burden, stimulate transdisciplinary science, and improve cost-effectiveness (Zuckerman et al., 2016).

Step 4: Implement Individual Research Studies that Maximize Causal Inference and Policy Relevance

Step 4 corresponds to the conduct of individual research studies, with an emphasis on those that strengthen causal inference and are of

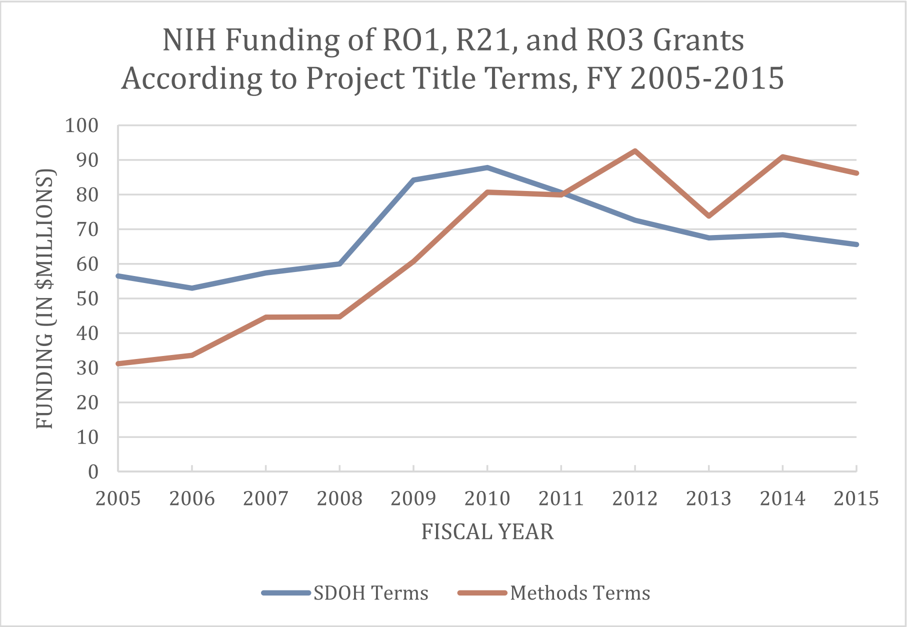

Fig. 2. SDOH Terms: SDOH = Social Determinants of Health. Funded research projects were included in the total if they included any of the following terms in their titles: "social determinants of health", "neighborhood", "income inequality", "social capital", "social support", "social policy", "socioeconomic status", "SES", "poverty", "race/ethnicity", "gender", "policy", "policies", "social cohesion", "health disparities", "health inequities", "contextual", or "multilevel"

Methods Terms: Funded research projects were included in the total if they included any of the following terms in their titles: "natural experiment", "randomized experiment", "RCT", "randomized trial", "randomized controlled trial", "community trial", "community intervention", "meta-analysis", "quasi-experimental", "quasi-experiment", "decision analysis", "economic evaluation", "cost-effectiveness", "cost-benefit", "priority-setting", or "evidence-based".

direct policy relevance. These studies include etiologic studies of various designs (e.g., natural experiment designs and observational studies adopting methods to strengthen causal inference such as instrumental variable analysis (Kim, 2016), difference-in-difference analysis (Komro et al., 2016), and inverse probability weighting (Hernán and Robins, 2006)), policy simulation and microsimulation (Speybroeck et al., 2013; Spielauer, 2011), multilevel analyses to avoid ecological fallacy and reduce cross-level confounding, decision analysis studies, comparative effectiveness studies (Teutsch and Fielding, 2011), and economic evaluation studies e.g., cost-effectiveness analyses (Luyten and Beutels, 2016; Whitehead et al., 2004). Through the systematic coordination of priorities and guidelines with academic journals and funding agencies in *Step 3*, feedback from *Step 5* to identify where knowledge gaps exist, and evidence-based guidelines for scaled-up interventions/policies in *Step 6* to indicate interventions/policies of interest, studies with more robust designs and higher policy impacts should be more closely aligned with population health priorities over time.

Step 5: Synthesize the Evidence Base across Studies

In this fifth step, a synthesis of the evidence based on individual studies would be made through systematic reviews, meta-analyses, and comparative effectiveness analyses. For example, Cochrane (n.d.) conducts systematic reviews of randomized controlled trials and observational studies, including those in public health. This evidence synthesis needs to carefully consider the strength of evidence based on each individual study, including taking into account the methodology and study design applied and the full weight of biases still inherent to the study, particularly in observational studies.

Recent reviews indicate the lack of evidence for many interventions on the social determinants of health (e.g., unemployment, housing, and education) (Bambra et al., 2010). Likewise, there is mixed to limited evidence on the impacts of social and economic policies (such as on early childhood education) (Thornton et al., 2016; Osypuk et al., 2014) and income-related policies (such as policies providing income support) (Aron, n.d.; Taylor et al., 2016) on population health.

Clear limitations also exist on the translation of knowledge into public health policy (Brownson et al., 2009). For example, in a review of public health laws between 1907 and 2004, scientific evidence was provided for only 6.5% of laws, and no information was given on their effectiveness (Hartsfield et al., 2007). Similarly, the Centers for Disease Control and Prevention (CDC) systematically reviewed the evidence base for the effectiveness of population-based public health programs, and found that preventable fractions were reported for only 4.4% of interventions (Thacker et al., 2005). Overall, there is a lack of rigorous evidence needed to make evidence-based guidelines for future interventions and policies (*Step 6*). Such evidence is critical if we are to successfully bridge the epidemiology-policy divide.

Step 6: Set Guidelines for Scaled-Up Population Interventions/Policies

In this penultimate step, guidelines would be made based on the synthesis of knowledge in *Step 5* and the existing evidence for interventions and policies. For example, the U.S. Department of Health and Human Services launched the CPSTF to produce the Guide for Community Preventive Services (Community Preventive Services Task Force, n.d.-a). This guide consists of evidence-based recommendations on public health interventions to save lives and improve quality of life, with the goal of informing decision-making of government health agencies. While more than 235 health topics have been evaluated to date, evidence of effectiveness on more than half of these interventions has been deemed insufficient to make recommendations (Briss et al., 2000). Evidence-based guidelines should also generate a feedback effect in guiding the setting of priorities (*Step 2*), the priorities that should be communicated to funding agencies and journals (*Step 3*), and motivating the individual studies that are conducted (*Step 4*).

As one exemplary guideline, the World Health Organization (WHO) published the Adelaide Statement on Health in All Policies (HiAP) in 2010 to assist policymakers in integrating considerations of health, well-being, and equity for policies across multiple health and non-health sectors e.g., education, housing, transportation, and urban development (WHO, Government of South Australia, 2010). This HiAP approach has been adopted in several jurisdictions, including the U.S. state of California (Rudolph et al., 2013). A HiAP approach to attain objectives on the social determinants of health has further been encouraged by Healthy People 2020, the CDC initiative which establishes national goals for policies and programs to address major health challenges facing the country (Koh et al., 2011). While it may be unrealistic to expect that every policy decision is guided by evidence (Anderson et al., 2005), such initiatives should be based on evidence where possible. The Secretary's Advisory Committee on Healthy People Objectives for 2020 has advised that all federal agencies be required to include Healthy People in their strategic plans (Secretary's Advisory Committee on Health Promotion and Disease Prevention Objectives for, 2010).

Taking this a step further by making this a mandatory inclusion would facilitate cross-agency collaborations and strengthen a HiAP approach.

Step 7: Implement and Evaluate Scaled-Up Population Interventions and Policies

In this final step, interventions and policies would be implemented and evaluated, such as according to the CDC framework for program evaluation (Koplan et al., 1999). Results would then feed back into the evidence base (*Step 5*). This is in keeping with the recommendation at the federal level for evidence-based social policy initiatives that there should be continuous evaluations of projects and programs during implementation (Muntaner, 2013). The expected outcomes of these efforts would be reductions in the burden of disease (*Step 1*). These efforts would also be anticipated to reduce the priority of addressing these exposures (*Step 2*, indirectly via *Step 1*). In addition, evidence on scaled-up intervention/policies could be used to directly inform the priority-setting process of *Step 2*.

The emergent fields of systems science and dissemination and implementation (D&I) science can also be drawn upon to bridge the epidemiology-policy divide. For example, as noted in Fig. 3, some of these paths involve reciprocal feedback loops. Systems science methods can incorporate such complex non-linearities and feedback loops into the modeling process (Mabry et al., 2010), and can thereby help identify more sensitive leverage points within systems.

As Brownson et al. (2018) and the Institute of Medicine (Gold et al., 2011) have argued, the need for systems science approaches is grounded in the fact that public health problems are complex and have upstream causes that are both multilevel and interrelated. Systems science models can help elucidate such pathways and can help assess the benefits and harms of policy and intervention options, thereby supporting evidence-based policy decisions. Key systems science methods include agent-based modeling, network analysis, system dynamics, and microsimulation. Applications of these methods have burgeoned in the public health literature over recent years (Luke and Stamatakis, 2012). For example, system dynamics modeling has been used by the WHO to influence its global health policy on polio from control to eradication (Thompson and Tebbens, 2008), and agent-based modeling has simulated how flu vaccination, antiviral use, and school closure strategies could mitigate an influenza epidemic (Lee et al., 2010).

D&I science, which systematically investigates the dissemination and implementation process (i.e., processes which occur between *Steps 6 and 7*) by key audiences can be instrumental in translating findings into tools that the general public and policymakers are more likely to understand and support (Brownson et al., 2012). For instance, policymakers are most interested in tangible costs and benefits to their populations using real-life terms that they can understand, and they seek a brief research summary with clear policy recommendations (Jones et al., 2006; Brownson et al., 2009). Yet a recent review of policy dissemination and implementation research funded by NIH showed that the proportion of funding for policy dissemination and implementation projects ranged from 14.6% in 2007 to 8.0% in 2012 (Purtle et al., 2015). This level of investment suggests necessary improvements to better influence evidence-based policy to improve population health. Along with having a strong evidence base and a well-defined strategy to act, harnessing political will is integral to policy implementation, particularly when policymakers may be focused on short-term outcomes and political imperatives for their constituencies (Exworthy, 2008; Richmond and Kotelchuck, 1991).

Political will is influenced by both supply side factors (i.e., what influences politicians and legislators) and demand side factors (i.e., the participation of citizens in political activities). On the supply side, political scientists have warned how campaign financing can distort the actions of representative democracy; hence, campaign finance reform can be a solution. On the demand side, politically-active citizens can generate political will through grass-roots activities such as coalition building, organizing petitions, and contacting politicians, which can help to pressure politicians to respond accordingly (Petticrew et al., 2004).

Importantly, policymaking occurs not in isolation but through networks of stakeholders—individuals, coalitions, and organizations—and implementing qualitative methods as well as systems science methods such as social network analysis to better delineate this networking and social influence process is critical (Exworthy, 2008; Petticrew et al., 2004; Tam Cho and Fowler, 2010). In 2016, the U.S. Commission on Evidence-Based Policymaking, established by the bipartisan Evidence-Based Policymaking Commission Act, developed a strategy for increasing the availability and use of data to build evidence about government programs (*Commission on evidence-based policymaking*, n.d.-b).

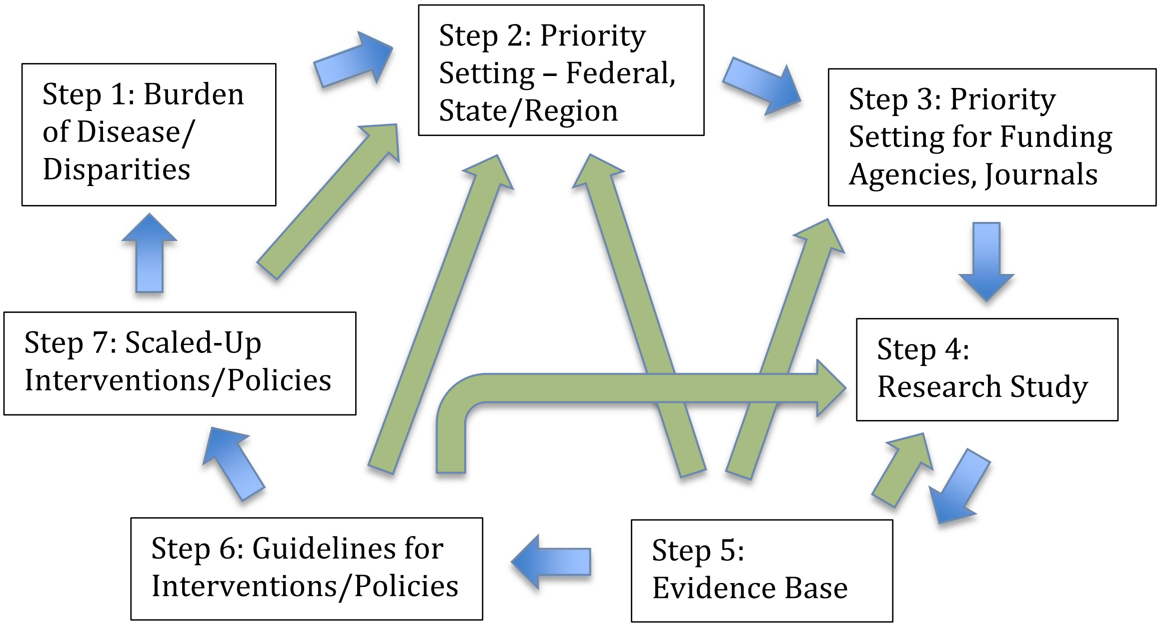

Fig. 3. Key elements of a consequential and evidence-based framework including reciprocal feedback.
Blue arrows indicate forward progression from one step to the next. Green arrows indicate reciprocal feedback.

Table 1

Elements of a consequential and evidence-based framework at the federal and state/regional levels to optimize population health.

Step	Key gaps/barriers that would be addressed	1) Key institutional stakeholders 2) Epidemiologist's role	Key outcomes/actions
1. Characterize burden of disease/health disparities/ emerging threats	Health, economic, and preventable burden of disease and health disparities still not comprehensively characterized at all geographic levels	1) Federal and state health agencies (e.g., CDC), non-profit organizations (e.g., American Heart Association) 2) Conduct descriptive epidemiology and economic assessment of burden	Estimated health, economic, and preventable burden of disease mortality and morbidity (disease incidence, DALYs, and QALYs) at federal, state/province, county, city, and neighborhood (census tract) levels; measurement of health inequities along axes including gender, race/ethnicity, socioeconomic status, geography; assessment of emerging threats (e.g., Zika virus, obesity and opioid epidemics)
2. Priority setting at federal & state/regional levels	Priorities set at federal and state/regional levels not adequately informed by health, economic, and preventable burden of disease and disparities and should consistently include the social determinants of health	1) Federal and state/regional agencies (e.g., CDC) 2) Serve as member of priority-setting panels	Results from implementing priority-setting method e.g., preference survey method, simplex method
3. Priority-setting by grant funding agencies, scientific journals	Funding agencies and journals may not systematically account for priorities based on health, economic, and preventable burden of disease and health disparities including the social determinants of health and studies with direct policy relevance Impacts of applied policy research not adequately measured using conventional indicators	1) Public and private grant funding agencies; scientific journals; academic and research institutions 2) Serve as administrative staff member at funding agencies, and member of grant review panels and journal editorial boards; serve administrative roles within academic and research institutions	Funding agencies and journals prioritize research on the social determinants of health and methods with direct policy relevance, and studies that use rigorous study designs Funding agencies and journals request structured information to better identify the public health significance/impact of submitted research and incorporate reporting of alternative metrics as measures of short-term policy-related influences
4. Implement research studies maximizing causal inference & policy relevance	Lack of etiologic, policy simulation, economic evaluation, systems science, dissemination & implementation studies on the social determinants of health and that have direct policy relevance Research agenda undertaken to inform policy may be viewed as tangential by those who make tenure and promotion decisions and may be avoided by early-career faculty and female and minority faculty	1) Academic and research institutions 2) Principal investigator/collaborator; administrative roles within academic and research institutions	Etiologic, policy simulation, economic evaluation, systems science, dissemination & implementation studies Use of alternative metrics that can measure policy-related influences of research studies
5. Synthesize evidence base across studies	Lack of systematic reviews, meta-analyses, economic evaluations, decision analyses, and comparative assessment/effectiveness studies on the social determinants of health	1) Academic and research institutions 2) Principal investigator/collaborator; administrative roles within academic and research institutions	Systematic reviews, meta-analyses, economic evaluations, decision analysis, comparative assessment/effectiveness studies
6. Set guidelines for scaled-up population interventions/ policies	Currently limited evidence-based guidelines on the social determinants of health (e.g., HiaP) at the federal and state/regional levels	1) Federal and state health agencies (e.g., CDC), non-profit organizations (e.g., AHA) 2) Member of expert panels/taskforce to develop guidelines	Population health intervention/policy guidelines (e.g., HiaP, guide to community preventive services) on the social determinants of health at the federal and state/regional levels
7. Implement & evaluate scaled-up population interventions/policies	Lack of implementation and evaluation of evidence-based interventions/policies on the social determinants of health at the federal and state/regional levels	1) Federal and state/regional health agencies (e.g., CDC) 2) Principal investigator/collaborator	Implementation and evaluation of population-wide interventions/programs/ policies on the social determinants of health at the federal and state/regional levels

The evidence base on interventions and policies gathered in *Step 5* and contributed by *Step 7* would ideally find its way to this commission, through an effective dissemination process.

3. The multiple roles of epidemiologists

Notably, epidemiologists play multiple pivotal roles in all seven steps of this framework as well as in the applications of systems science and D&I science methods. For example, epidemiologists provide descriptive statistics and measures to characterize the burden of disease (*Step 1*); serve as members of priority-setting panels (*Step 2*), editorial boards (*Step 3*), and panels to systematically review and make recommendations on scaled-up population interventions (*Step 5*); and assume lead roles as principal investigators and collaborators in epidemiologic studies, including observational studies, natural experiments, simulation studies, and interventions as well as economic evaluation studies (*Steps 4*, *5*, *and 7*) (Table 1). Epidemiologists can also contribute to systems science and D&I science research. Professional epidemiologic and public health associations such as the ASPPH, SER, and IEA should educate their members about this overarching framework and the diverse and critical roles that epidemiologists can play within it.

4. A social epidemiology-policy example

In the Appendix, a detailed example is provided of reframing studies towards policy in the social epidemiology sphere, based on a recently-published policy simulation study (Kim, 2018). The relevance of this simulation study to each of the seven described steps is further annotated in supplementary *Table S1*.

5. Conclusions

Widespread and systematic adoption of a consequential and evidence-based framework for epidemiology will help lay the critical foundation for more cost-effective approaches to address real-world public health challenges and opportunities that Americans face over the life-course. This framework includes the priority-setting of problems at the federal and regional/state levels, and it should strengthen where possible the alignment of public and private research funding and journals with these priorities. The latter coordinated efforts will provide key incentives for researchers to implement more policy-relevant research studies and more rigorous methods and study designs, which in turn will enhance the evidence base for disease prevention. Over the long term, implementing this framework and providing incentives or mandating elements of it (the latter where more direct leverage is needed) should help bridge the divide between epidemiology and policy, and optimize the use of increasingly constrained resources to reduce disease burden and promote the nation's health.

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Appendix A. Supplementary data

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