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Commentary

The Unique Space of Epidemiology: Drawing on the Past to Project Into the Future

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Epidemiology has always filled a unique space. It lies squarely at the intersection of the social and biological sciences as well as at the intersection of knowledge generation and the translation of that knowledge into actions. Today, new data sources, new methods, and continued population health problems create opportunities and challenges for epidemiology. In this commentary, 4 areas of opportunity for epidemiology are reviewed: 1) the continued value of precise description; 2) a rigorous yet broad and practical approach to drawing conclusions about causes; 3) embracing methodological diversity; and 4) retaining a strong connection to public health practice and policy.

causal inference; evidence; multilevel study; public health practice; systems

Epidemiology has always filled a unique space. It lies squarely at the intersection of the social and biological sciences as well as at the intersection of knowledge generation (in an abstract sense) and the translation of that knowledge into actions (i.e., practice and policy). This aspect of epidemiology is what makes the field simultaneously intellectually fascinating and socially relevant: science at its best. It also makes epidemiology a hybrid and, therefore, inevitably prone to perpetual reflection on its true identity. The space epidemiology occupies also helps explain the many debates on the substance and methods of epidemiologic inquiry that have long characterized the field.

Today is no different: There is rich and ongoing debate within and outside epidemiology on the epidemiologic approach to health problems and its value. Some of this debate is primarily among epidemiologists and focused, for example, on how the validity of causal inference from epidemiologic studies can be maximized. But some is also external and questions in a fundamental way the validity of scientific conclusions based on studies of populations more generally. This latter debate is present not only within the biomedical health community (which, despite lip service to population-level factors in many of its actions, continues to prioritize biology and genetics as drivers of health) but also, and of great concern, in the policy world, where findings from epidemiologic studies often face great scrutiny and are summarily dismissed in some circles.

Much of the debate on the approaches and value of epidemiology has been reiterated many times. But it is also true that advances in data and methods, a growing recognition of the value of interdisciplinarity in science, and the increasing number of policy-relevant questions about population health are creating new opportunities and new challenges for epidemiology as a field. In this commentary, I highlight 4 areas that provide opportunities for epidemiology. I conclude with a brief discussion of challenges ahead.

THE CONTINUED VALUE OF PRECISE AND FOCUSED DESCRIPTION

Description of the distribution of health and disease in populations has been the hallmark of epidemiology since its origins. Indeed, a basic tenet of epidemiology is that much can be learned from precise description of how health is distributed by person, place, and time. It can be argued that all observational studies (even those aimed at causal inference) are in their most fundamental essence very precise descriptions. In addition to aiding causal inference, accurate description has long been noted as critical for setting priorities for action and for targeting actions and resources. Descriptions, especially novel ways of describing even well-known phenomena like the social patterning of health, can be powerful tools for advocacy by communities and others. Description can focus on many aspects, including levels of health; distributions by place, social group, or other factors; and trends over time. Today, the advent of new sources of data and new methods to use that data make possible more and more sophisticated and potentially insightful descriptions of how health and disease are distributed in populations. Data that increasingly can be used to enhance description range from electronic health record data to social media data to epigenetic

markers. Environmental data (broadly understood), including satellite data and data extracted from sources like Google Street View, increasingly can be used to characterize health-relevant features of places (1, 2). Georeferencing and smartphones can be used to link data to time and place. New methods for integrating and processing these data can yield rich descriptions. Data collected for 1 purpose can be leveraged for other purposes (e.g., the use of national surveys to generate estimates for neighborhoods) (3). Statistical approaches can be used to derive reliable estimates of life expectancy or other outcomes across very small areas (4). Machine-learning methods and neural networks can be used to describe and synthesize the patterns observed, generating hypotheses for further inquiry (5). Capitalizing on these new enhanced descriptions will continue to be important to epidemiology.

A RIGOROUS YET BROAD AND PRACTICAL APPROACH TO DRAWING CONCLUSIONS ABOUT CAUSES

Much recent debate among epidemiologists has focused on causal inference from observational epidemiologic studies. This is important because causal inference is a fundamental goal of epidemiologic inquiry (6) and because for many reasons, including feasibility as well as inherent limitations of randomized trials for some important types of causal questions, observational studies will continue to be a major tool in population health research.

There is a long tradition of writing by epidemiologists on the limitations of causal inference from observational studies and on what can be done in the design or analysis of observational studies to minimize incorrect causal inferences. This focus on improving the rigor of observational studies has resulted in more careful attention to the challenges of causal inference, including explicit recognition of the assumptions involved, and has increased the use of more sophisticated analytical approaches.

An interesting aspect of the most recent debate has been discussion of what factors can be conceptualized as causes. The crux of the debate hinges on whether attributes like social class or even states like body mass index can be conceptualized as causes and, therefore, can be subject to causal inference from observational studies (7, 8). One view argues that only well-defined interventions are identifiable as causes because only they can fulfill key assumptions of causal inference (7). Others view this as unnecessary for causal conclusions to be valid and as excessively narrow and seriously constraining to epidemiologic causal inquiry (8).

At its core, this is a philosophical debate about what we mean by causes. But it is important because it has implications for what is considered to be within or outside the realm of causal inquiry in epidemiology (and population health more generally). One way to resolve this debate is to think of causal factors of interest to epidemiologic inquiry as part of a continuum ranging from broad upstream factors that may shape multiple, subsequent causal processes to specific identifiable interventions under specific circumstances (Figure 1). As we move in one direction along the continuum, the factors are more distal and operate in complex ways, often through multiple mechanisms that can change over time. Hence, the implications for interventions are not always straightforward, because multiple possible interventions could be possible and not all interventions may work the same way or have the same impact. In addition, there can be strong confounding and many intermediate steps (or mediating pathways) may be involved in the causal processes. As we move in the other direction along the continuum, the specificity increases to the point where the causal question of interest pertains not only to a very narrowly defined factor but to a defined and practicable intervention on that factor itself, and even to a defined and practicable intervention under specific conditions. Interestingly, this very specific formulation is closely related to implementation research, with its focus on understanding how a given well-defined intervention may function in different contexts.

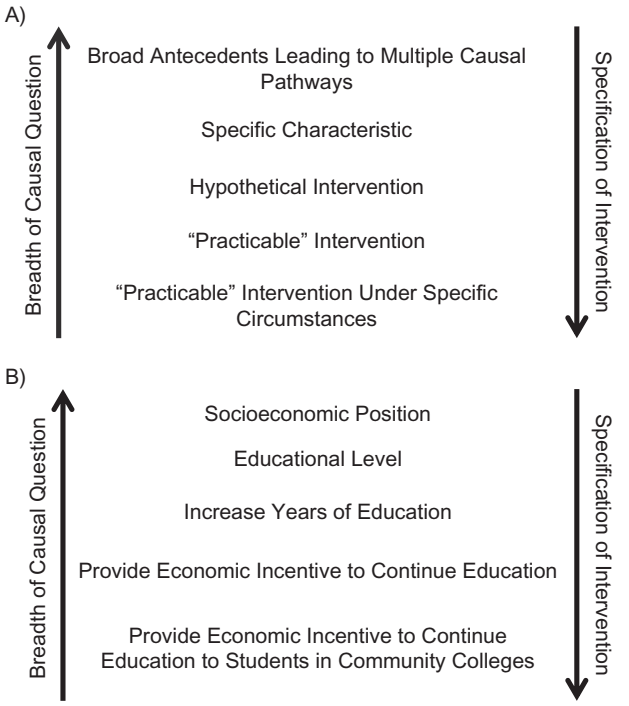

Figure 1. A) The causal continuum of interest to epidemiology. B) An example of the causal continuum.

Certainly the very narrow focus has distinct advantages for our ability to cleanly identify a causal effect. However, if we restrict epidemiologic inquiry to these very well-defined interventions, we risk missing the opportunity to identify broader factors that drive the big patterns we see in population health. As others have noted, identifying these distal factors is a necessary first step to identifying the specific causal processes, and eventually the interventions applied to them, that then can be tested in a more specific way (9). Of course, the complex nature of these distal factors (which makes them difficult to define and measure), their associations with other factors (often resulting in strong confounding), and that they operate through multiple intermediaries over long periods make the isolation of their causal effects especially challenging. In an additional illustration of the interrelation between distal causes broadly defined and the effects of specific interventions, inferences about the impact of specific interventions can often help strengthen the causal story about the more distal determinants themselves.

METHODOLOGICAL OPPORTUNISM AND DIVERSITY

The complexity of the causal processes we study in epidemiology and population health and the desire to generate practical, applicable knowledge require us to be broad and even opportunistic in the methods we use. Observational studies are in some way the hallmark of methodologic opportunism: Carefully observe what is going on, capitalize on "natural" variation, and take advantage of it to draw conclusions about what might happen if things changed. But we need to go beyond observational studies.

It is common to note that observations can lead to experiments to confirm causal inferences through experimental manipulation of the causal factor of interest (or a factor involved in the causal process linking a distal determinant to health). It is also true, but less frequently acknowledged, that results of experiments may raise new questions that can sometimes be addressed through new observational studies. Observations and experiments, in turn, can inform modeling or simulation studies, especially those capturing features of complex systems. These simulations or models can be used to integrate and better understand the implications of what we know from observational studies and experiments, as well as insights from qualitative studies. This is important because the causal processes driving population health frequently are likely to involve feedbacks, contagion processes, conditional effects, and path dependencies (10, 11). But complex systems approaches, when thoughtfully done, often raise new questions that can only be answered through a return to empirical analyses, be they observations or experiments.

Last, in public health, actions must sometimes be taken even when only partial evidence exists. Sometimes actions that could have health impacts are taken for reasons completely unrelated to health (e.g., expansion of a public transportation system or a new income support program). The evaluation of these actions (e.g., through the analysis of natural or quasi experiments) is critical not only to provide valuable information on the impact of the specific policy or intervention itself but also to help clarify and strengthen the causal story.

For the complex causal processes we study in population health, no single method will suffice. They all have their inherent limitations and all feed into each other. To strengthen their conclusions, epidemiologists must opportunistically integrate all 4 methodological approaches (Figure 2). Of course, it is also important that we integrate insights from other sciences (e.g., qualitative information from the social sciences or biological information from the biomedical sciences) in formulating quantitative questions and interpreting the results of quantitative analyses. The types of factors that may drive population health and the complexities involved necessarily require a broad view of the types of evidence that may be relevant in drawing meaningful causal conclusions (12).

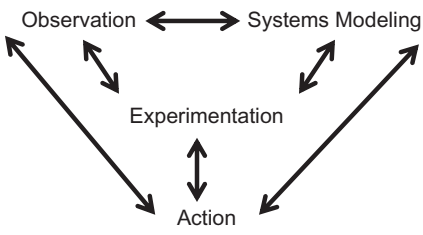

Figure 2. An evidence-generating system for population health.

RETAINING OUR CONNECTION TO PUBLIC HEALTH PRACTICE AND POLICY: WHAT DOES IT MEAN TO BE "CONSEQUENTIAL"?

There has been much debate on epidemiology's connections to practice and policy. Certainly, an eye toward intervention and policy is characteristic of the epidemiologic approach. It is what defines the field and makes it unique, socially relevant, and challenging, too.

Recent discussions about how to make epidemiology "consequential" have emphasized the need for epidemiologists to focus their efforts on identifying policies and interventions that can improve health, rather than on "simple" description or etiologic research (13). Certainly, a greater emphasis on identifying the most effective ways to improve health and reduce health inequities is desirable. Direct investigation of policy and intervention effects is a challenging area in which epidemiologists should be more involved. However, there are many ways in which epidemiology can motivate and inform the types of actions needed to improve population health.

Description of the magnitude and distribution of a problem, especially in ways that highlight previously unknown or underemphasized patterns, can be critical in motivating action or intervention. Epidemiologic approaches are fundamental to surveillance and monitoring, both of which are important for policy and interventions. The description function of epidemiology is an often under-recognized way in which epidemiology informs policy.

Research focused on identifying causes (i.e., etiologic research) also will continue to be relevant to a "consequentialist" epidemiology. This is easy to see when the focus of causal inference is on well-defined interventions, but I would argue that it remains true even when the focus is on identifying upstream drivers of health. In some cases, policy can be supported through broad description and characterization of distal determinants, including new insights into the magnitude of their impact or mechanistic understanding of exactly how they affect health. In other cases, more specific evidence related to the impact of a concrete intervention is necessary. Balance, of course, is critical: Too much emphasis on repeated description of a known pattern without moving in the direction of refining causal understanding and identifying the impact of specific policies or interventions can lead to stagnation. But a broad view of what is consequential is important: What is relevant or consequential policy at a given time depends on the state of knowledge and the particular policy needs and questions in a given substantive area.

CHALLENGES AHEAD

Certainly there are many opportunities and challenges for epidemiology. Here, I highlight 3 I feel are especially important. A first challenge is ensuring a continued and broadened engagement of multiple disciplines relevant to population health (e.g., biology, behavioral science, environmental science, economics, sociology, urban planning, computing and

data science, complexity science) in our research and training programs. This is important not only for substantive reasons but also for the methodological tools and insights these fields can bring to epidemiology.

A second major challenge is sustaining and defending the rigor and value of the population approach embraced by epidemiology as fundamental to scientific knowledge and to informed policy for population health. There continues to be (sometimes for good reason but often for reasons linked to special interests) persistent questioning of the use of any epidemiologic data to inform policy. How can we best make the case for what we can reliably learn from epidemiology while acknowledging the limitations? How we can transcend simplistic thinking that reinforces a false dichotomy between the individual and the population, as if population patterns can always be explained by individual level factors or, contrarily, as if population patterns can be understood without reference to the individuals that compose them?

A third challenge is the responsibility we face to use the tools of epidemiology to grapple with the most vexing population health problems we face today. These include persistent health inequities; the impact of environmental sustainability on health, and vice versa; and the continued increase of noncommunicable diseases in many parts of the world in concert with new or re-emerging infections. These are complex and messy problems, no doubt. The questions they raise are not amenable to controlled clinical trials or laboratory experiments. And yet we need action based on the best available evidence possible and evaluation of that action so we can learn about causes generally and also about what works. This is where today, as in the past, epidemiology comes in.

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