Commentary

Beyond Black Box Epidemiology

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"Black box epidemiology" is the most recent addition to a long list of disciplinary subgroups although few practitioners would likely trumpet their allegiance to it. Epidemiology's many subdisciplines represent the wide applicability of a growing and dynamic field and, paradoxically, an element of professional incohesiveness. Nowhere is this paradox more evident than in a provocative discussion in the recent literature; I call it the "black box" debate. Its provocativeness stems from strong claims and counterclaims regarding a colorful metaphor. Its importance lies in its potential to unite epidemiology in all its disciplinary complexity.

My purpose is to briefly describe the historical threads of this discussion, weaving in the black box concepts of systems theory. What arises is a foundation for building conceptual bridges within epidemiology. Two problems also emerge, the solutions of which may frame future discussions. The first involves weaknesses inherent in systems theory. The second concerns the divisive forces creating conceptual rifts among epidemiologists, including contributors to the black box debate.

Historical Background

The history of epidemiology can be seen both as discrete eras or paradigms[1] and as gradually evolving concepts.[2] Some consider history a fabric woven of many threads.[3] The black box discussion, occurring at the junction of two eras and reflecting evolving paradigms, comprises at least two such threads: the first in papers by Peto,[4] Vandenbroucke,[5] Savitz,[6] and Skrabanek,[7] and the second in papers by Loomis and Wing,[8] Krieger,[9] and Susser and Susser.[10]

The First Thread

In 1984, Peto described two complementary approaches to cancer epidemiology and prevention.[4] The first he called a "mechanistic" approach; it emphasized the biology of carcinogenesis. The second he dubbed the "black box strategy" because it ignored biology in favor of behavioral risk correlates. Peto noted its "low scientific repute." Vandenbroucke echoed this sentiment when he argued that epidemiology must integrate molecular biology with its traditional black box strategy or suffer academic disrepute.[5] Recently, Savitz[6] defended the tradition of black box epidemiology, arguing that it allows for disease prevention in the absence of a clear understanding of mechanism. Skrabanek,[7] on the other hand, marked black box strategies as futile exercises in non-science and an "embarrassing liability" to those who dismantle the black box in their search for "universal laws."

The Second Thread

For Loomis and Wing,[8] neither black box strategies nor molecular-based strategies are adequate. These researchers suggest an integration of biology, behavior, and sociopolitical forces. Krieger[9] also calls for a broader conceptualization, as have Susser and Susser, who proclaim the advent of an expansive era called "eco-epidemiology," stretching from societal dynamics to intracellular dynamics.[1,10] These second-thread

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authors assume that black box and mechanistic strategies can be integrated. But given the strongly negative opinion of black box strategies found in the first historical thread,[4,5,7] it is not clear how that integration can occur. An examination of the nature of black boxes, black box thinking, and their parent concept, systems theory, provides a clue.

Black Box Epidemiology

One first needs to take a black box to be a metaphor[11] for the individual organism and take black box thinking to be a methodology that ignores rather than explores the insides of the box. One then places the black box near the middle of a structure of scientific knowledge that has recently been labeled as a set of Chinese boxes—each one nested inside another.[10] There, the environment, interpersonal dynamics, and social forces such as race, ethnicity, economics, and politics lie "above" the level of the individual, while organ systems, cells, genes, proteins, atoms, and quarks lie "below" that same level.[12,13] Black box thinking labels the methodologic approach that ignores biology and thus treats all levels of the structure below that of the individual as one large opaque box not to be opened.

For some,[7] black box thinking is indefensible—hence, the pejorative connotation. A serious problem with such an opinion, however, is that the same negative labeling can apply to scientists who ignore other parts of the structure. After all, unopened black boxes lie above and below every level. Thus, black box thinking labels molecular biologists who fail to explain DNA repair in terms of quantum forces or other entities below molecules. It also characterizes molecular epidemiologists who fail to examine the behavioral implications of genetic knowledge.

An unfortunate legacy of the first historical thread, therefore, is a pejorative label for epidemiologists who constrain their conceptualization of the proper domain of investigation. To reach the more expansive view found in the second historical thread, a constructive change in the way we use the ideas of black boxes and black box thinking is necessary. This change represents more than a new set of labels; it is a change in the way epidemiologists view what is important in disease etiology and prevention, a change in conceptual framework. It is called a general systems approach and ironically, a "black box" is neither a limiting construct nor a derogatory label. Rather, it is a central precept.

A simple system is composed of inputs, outputs, and mathematical model(s) in between.[14] A 2-by-2 table, the essence of epidemiological analysis, is a simple system, with the input to the black box being the counts of diseased and nondiseased classified by exposure status, the output being the relative risk estimate, and the model being a formula for the odds ratio. Employment selection and its impact on health status—the "healthy worker effect"—is another example,[15] as are infectious disease transmission processes[16] and population screening programs.[17]

Engineers have developed systems analysis most extensively, and they teach that a complete understanding of the inner components of a black box at any level of inquiry is impossible.[18] All mathematical models are imperfect representations of reality, although a good model of the inner components is preferred if controlling output is the goal. A central premise of systems theory is that the knowledge of the box's interior and control of its input-output relationships are closely linked. A wide variety of models, including nonlinear, linear, static, or dynamic, are possible; the best model is one that best represents input-output measurements.

More complex systems arise when the size and scope of the mathematical model are increased (e.g., through parameterization) and black boxes are linked together—that is, when the mathematical models developed within the boxes are linked together. The input to one box can represent the output from another. Indeed, when faced with a problem as complex as that represented by the broad structure of scientific knowledge described earlier, a systems analyst will use a "divide and conquer" strategy in which subsystems—the black boxes at each level of the structure—are investigated separately and independently, followed by a more detailed characterization of their connections (K. Lilly Jablokow, personal communication).

Even this incomplete presentation of the principles and practice of systems theory warrants the conclusion that the approach has merit. I believe epidemiologists should embrace rather than denigrate the idea of black boxes.

Beyond Black Boxes

Despite its many strengths, a systems approach also has weaknesses, especially when a good mathematical model is not available at a particular level of explanation.[19] Systems theory is not very effective for solving qualitative problems of morality, law, politics, knowledge, attitudes, beliefs, and social forces, to name a few.

Social forces—values—within the scientific community of epidemiology deserve consideration. Values have an undeniable influence on the way epidemiologists think[20] and therefore on the way we understand the relationship between the ever-growing list of subdisciplines and the level(s) of the structure of knowledge they examine. Molecular and behavioral epidemiology provide an apt illustration; not everyone is equally enthusiastic about a balanced effort between the two. Although it is reasonable to conceptualize connections from the "top" to the "bottom" of the structure of scientific knowledge,[21] epidemiologists may not be willing to make connections between different levels nor suffer others to do the same. The sharp debate between proponents[6] and opponents[7] of black box epidemiology reveals epidemiologists' vastly different worldviews about the conduct and interpretation of research involving behavior and biology.

Philosophers call such stark differences "incommensurabilities,"[22] and there is something to be said for examining this problem in terms of the philosophy of science.[23] There it is claimed that social forces can foster divisiveness[24] such as that seen in epidemiology, with its relatively new subdisciplines of public health[25] and clinical epidemiology. Add to this trend toward subspecialization[26] a derisive voice[7] and sentiments such as the one that nonmedically trained epidemiologists lack sophisticated biological knowledge,[27] and the result is a social environment *within epidemiology* ripe for fractionation and replete with partially incommensurable methodologic paradigms[22] providing fodder for the black box discussion.

Beyond appeals to reasonableness[28] and disclosure,[29] countering such divisive forces requires a reassessment of some basic questions: What *is* the nature of epidemiology? What is our professional *telos*—that is, the goals internal to the practice of epidemiology?[30] Do we share a common vision and a common purpose? Answers to these questions may not come easily. As shown above, there is diversity in what counts as a legitimate scientific approach. And even if we could agree on a coherent scientific paradigm, we need something more than science to ensure our commitment to public health.[10] We need a common set of moral values,[23] yet we do not even have a clear consensus on something as basic as our obligation to public health.[31]

Recommendations

In closing, two recommendations emerge. First, there is a need to explicate and to agree on the basic values of the discipline in this era of professional incohesiveness. Perhaps the questions posed above will help frame such a discussion. Second, epidemiologists should get beyond the pejorative connotation of black box thinking by embracing a systems theory approach while remaining aware of its weaknesses. In so doing, they will secure access to the broad scope of scientific knowledge with the behavior of populations near one extreme and the behavior of molecules near the other. Toward that goal, and in the spirit of professional reunification consistent with the historical and metaphorical thrusts of this paper, I offer one more way to make black boxes at all levels of scientific knowledge a little less opaque.

In Anglo-Saxon times, the word *black* meant "pale," as in a pale-cheeked maiden or a pale light. The words *bleak* and *bleach* come from the same root. How the meaning changed so drastically over time is not clear. Perhaps because a pale complexion takes on a bluish tint, the designation was passed on to the darker colors of the spectrum, and finally in modern English it came to mean the total absence of color.[32] Whatever the case, history teaches that a black box need not be an opaque box. Rather, it is a pale window through which we peer, contemplating the complexities hidden inside ourselves and catching the pale reflections from the boxes surrounding us. □

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