LEADING ARTICLE

Is Molecular Epidemiology a Germ Theory for the End of the Twentieth Century?

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A recent article in this journal by Vandenbroucke drew a parallel between the possible intellectual fate of some current ideas in epidemiology and the last century's miasma theory of epidemics. Like some nineteenth century investigators, many contemporary epidemiologists are indeed guided by the principle that the origins of disease are environmental in a very broad sense. This is sometimes called the 'black box' view of epidemiology, and it emphasizes the documentation of exposure-disease associations in conjunction with the idea that disease can be prevented by altering the environment without the need of detailed knowledge of pathogenic mechanisms. Vandenbroucke's thesis is that epidemiologists who subscribe to this view, like the miasmists, their philosophical predecessors, are destined to be the losers in a struggle with a superior scientific idea. For the miasmists that competing idea was the germ theory of disease; for the epidemiologists of today, in his view, it is molecular biology.

Such exhortations that epidemiology must alter its philosophy and methods to survive as a legitimate scientific discipline are not unusual but they are often based on a distorted view of the history and goals of epidemiology. This view is derived from a misinterpretation of the last century's intellectual contest between theories about the origins of mass disease. The conventional wisdom of today is that those nineteenth-century epidemiologists who subscribed to the theory that epidemics are completely explainable by the presence of specific agents in all affected populations won that contest because they were right, that is, because such agents are, by definition, the unique causes of disease. The virtue of their ideas is supposedly proven by the subsequent conquest of infectious disease by scientific medicine and the downfall of competing causal theories.

The achievements of scientific medicine in this century obscure other aspects of these historical events however. The nineteenth century contest between the contagion and miasma theories of the origin of epidemics is often held up as a singular turning point in the history of medical thought, but that contest grew from a tension as old as western medicine between the heroic capabilities of the healer and the often unglamorous work of the hygienist. The same tension continued even after the germ theory of disease was widely adopted, as the concept of specific aetiology and ideas emphasizing the role of environment alternatively gained and lost favour throughout this century. The fact that the debate continues today in the competition for grant money between high-technology molecular investigations and classical exposure-disease studies indicates that approaches philosophically descended from the germ theory have not dispatched their competitors as successfully as they are often credited with having done.

Moreover, the triumph of scientific medicine over epidemic disease is not the clear victory commonly supposed. The great plagues of Europe disappeared long before the emergence of bacteriology. In the late nineteenth and early twentieth centuries, impressive declines in mortality also took place before either effective medical therapies or prophylactic treatments had been developed, and occurred largely as a result of social and environmental change intended to improve the quality of life and enhance economic production.

What, then, is the importance of this history today? Both of the last century's leading causal theories are certainly still with us, but neither has retained its nineteenth century form. It is virtually beyond dispute that
certain specific agents are necessary for disease to occur. Nevertheless, in infectious disease epidemiology, the position accorded to infectious organisms has changed markedly in the last hundred years. The intellectual dominance of Koch’s postulates declined by the early twentieth century, and infectious agents by themselves came to be regarded as incomplete explanations for the occurrence of mass disease. In spite of their logical power, Koch’s causal criteria lead to an oversimplified view of infectious disease aetiology, and because of this realization, the original theory has been broadened to admit other aspects of the agent, the environment, and the host—including characteristics of the population of which the individual host is a part.

At the same time, factors like history, geography, and social status remain exceedingly powerful predictors of the health of human populations, as they were a century ago, and social change is still an important force behind trends in disease rates. These observations are usually taken as evidence for the aetiological role of environment. For its part, though, the environmental theory of disease aetiology has changed by increasingly taking on logic and methods which mimic the identification of single aetiological agents and the quantification of their independent effects through experimentation. Despite their evolution along convergent paths since the nineteenth century, the descendents of the nineteenth century contagion and miasma theories retain distinct identities which imply that both theories are right, in the sense that each provides explanations not satisfactorily made by the other. However, their growing similarity demonstrates why they are both also wrong.

The modern incarnations of these theories are centred on agents of disease that are differently conceptualized, but similarly alienated from the ecological context in which they exist. Neither approach effectively addresses the interdependence of multiple agents or how human populations become exposed and susceptible to them. This failure derives from a view of populations as mere aggregations of individuals (ie vehicles for quantifying exposure-disease associations) rather than as organized groups with relational properties that cannot be deduced by measurements on individuals. While molecular techniques can directly address some important weaknesses of ‘black box’ environmental theories, they do not possess inherent scientific qualities that make them superior tools for understanding the determinants and distribution of disease in populations, despite their often-proclaimed advantages over other methods.

No specific method or technique can provide a solution, because the problems with existing epidemiological theories of cause arise from their fundamental conceptual, rather than technical, inadequacy.

To avoid having to make a choice between scientifically unsatisfactory alternatives, it is necessary to replace the meaning of cause underlying both the ‘black box’ epidemiology that Vandenbroucke called a modern miasma theory, and its complement, the contemporary ‘germ theory’ that argues for a mechanistic, molecularized epidemiology, narrowly focused on the discovery of a new class of agents. Despite their apparent antagonism, these epidemiological theories share derivation from a global scientific paradigm that has been termed Cartesian reductionism. In epidemiology this paradigm equates causal inquiry with discovering the inherent dose-response relationships between agents and diseases through rigorous hypothesis testing. The weakness of causal theories arising from the Cartesian paradigm is their failure to recognize that the action of interdependent parts (agents, aspects of the environment, and individuals) is not an immutable, ahistorical characteristic of those parts, but is, instead, dependent on the properties of the whole system in which they operate. The reductionist paradigm does not treat populations as structured, historical systems; this omission is analogous to a physiological paradigm that would ignore the development, differentiation, and organization of cells in an organism. This fallacy makes it clear that cause in epidemiology is not a property of agents, but one of complex systems in which the population phenomena of health and disease occur.

This concept of cause is not new. It has a long history connected to a line of thought that emerges clearly in Rudolf Virchow’s exploration, nearly a century and a half ago, of causal ideas ranging from cellular to social aspects of the origins of disease. The same conceptual thread has continued to our own time in writings that give a glimpse of the structure of an alternative epidemiological paradigm.

The success of epidemiology as a science will ultimately depend upon its ability to predict, explain, and act through the use of theory. John Snow’s work on cholera was important, not because he was a contagionist, but because he had a complex, integrative theory that was able to explain important observations and lead to practical intervention. The challenge for epidemiologists facing the 21st century is to develop similarly sophisticated theories of cause that acknowledge the complex systems in which the health-disease process is embedded. This entails embracing both new advances from laboratory science and old concerns about the role of environment without isolating either one from the whole systems of which they are essential parts. Meeting this challenge demands no less than a
paradigm shift in epidemiology, one which is being stimulated by the vast public health consequences of global environmental, demographic, and social changes now taking place.

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REFERENCES