

Choosing a Future for Epidemiology: II. From Black Box to Chinese Boxes and Eco-Epidemiology

ABSTRACT

Part I of this paper traced the evolution of modern epidemiology in terms of three eras, each with its dominant paradigm, culminating in the present era of chronic disease epidemiology with its paradigm, the black box. This paper sees the close of the present era and foresees a new era of eco-epidemiology in which the deployment of a different paradigm will be crucial. Here a paradigm is advocated for the emergent era. Encompassing many levels of organization—molecular and societal as well as individual—this paradigm, termed *Chinese boxes*, aims to integrate more than a single level in design, analysis, and interpretation. Such a paradigm could sustain and refine a public health-oriented epidemiology. But preventing a decline of creative epidemiology in this new era will require more than a cogent scientific paradigm. Attention will have to be paid to the social processes that foster a cohesive and humane discipline. (*Am J Public Health*. 1996;86:674–677)

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Whether the provocative factors are inherent in the population through their genes, their cells and their parasites; whether they are failures to meet environmental influences of social, physical or biological nature they constitute the concern of the epidemiologist. . . . Consequently, epidemiology must constantly seek imaginative and ingenious teachers and scholars to create a new genre of medical ecologists who . . . can interpret the interplay of forces which result in disease.

Thomas Francis¹⁹

Introduction

In this paper on the choices before epidemiology, we advocate a paradigm for an emergent era of eco-epidemiology. To connote the inclusion of systems at different levels, we term the paradigm *Chinese boxes*. This paradigm stems from a particular distinction between the “universalism” of the physical sciences and the “ecologism” of the biological sciences. It places epidemiology on the track of ecologism, a perspective we aim to explain and justify below.

The practical implication of a localizing ecological paradigm for the design of epidemiological research is that an exclusive focus on risk factors at the individual level within populations—even given the largest numbers—will not serve. We need to be equally concerned with causal pathways at the societal level and with pathogenesis and causality at the molecular level. Here we note that investigations at all these levels are found in the history of medicine and epidemiology since early times. Hippocrates was concerned with the effects of broad environmental conditions on health.¹ Later Galen, who emphasized the individual host in the form of the four humors, did not neglect the interaction of susceptibility with lifestyle. Paracelsus, in the 16th century, aimed to grasp multiple levels.² He tried to apply chemis-

try to medicine, and he also studied the influence of the stars on physiology.

The Need for a New Paradigm

The necessity and the potential of a new paradigm can be illustrated for the infectious disease of human immunodeficiency virus (HIV) and the chronic disease of peptic ulcer. While these two diseases were selected to represent infectious and chronic diseases of our time, each of them also shows a blurring of the distinction between infectious and chronic disease. This is itself a hallmark of the new era.

To understand and contain the global epidemic of HIV requires causal thinking at several levels of analysis. At the molecular level, the precision of molecular biology is required to determine the means and the timing of transmission and to find a way to interrupt it. At an intermediate level, specific social behavior of individuals fosters sexual and other forms of transmission of the virus. At the population level, the dynamics of the epidemic are governed by the prevalence of the infection itself as well as by other characteristics of the population—

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for instance, patterns of sexual relationships and of breast-feeding, prevalence of other sexually transmitted diseases, and nutritional factors such as maternal vitamin A levels. At the global level, the interconnections between societies determine the path of the infection. As investigators, we are naturally constrained by our capabilities and by the necessary reductionism entailed in firmly establishing the connection between one thing and another and, more especially, their causal relationships. Yet the best hopes for containing the epidemic rest upon a coherent strategy that can address all these levels.

Peptic ulcer similarly illustrates the limitations of a narrow frame of reference for a chronic disease.³ The causal framework of the gastrophysiologist is likely to focus on the wall of the stomach; that of the neurophysiologist, on the autonomic nervous system. The psychosomaticist expands the framework to include internal and environmental stressors, the human geneticist considers familiarity in blood groups and secretor status, and the microbiologist brings the recent discoveries about *Helicobacter pylori* to bear. The epidemiologist includes all the above and adds smoking as an individual risk factor.

But the mystery and the challenge of peptic ulcer for epidemiology lies at the ecological level of major secular change. We still have to unravel the factors that caused the peptic ulcer complex first to wax and then to wane. This condition (or complex of conditions) mysteriously reached a peak in the 1950s and then, no less mysteriously, began to decline. This was a cohort phenomenon that began its rise in cohorts born before the turn of the 19th century, with a steady decline in cohorts born thereafter.³ A fully adequate causal model for public health must explain the disease at the ecological level as well as at lesser and more refined levels of organization. This remains so even if the best explanation turns out to be the historical behavior of *Helicobacter* microorganisms.

Universalism vs Ecologism

The road is now open for epidemiologists to work at the same time at the molecular and the societal levels. To do so, we need to be guided by appropriate causal concepts, a matter already under discussion in epidemiology.⁴⁻¹⁰

Like all the sciences, epidemiology seeks generalizing concepts to explain the

causes of things. In the history of science, however, one can trace not one but two conceptual tracks. The well-described universalism of the physical sciences must be complemented by the often unacknowledged ecologism of the biological sciences. In contrast with universalism, ecologism entails localization and attention to the bounds that limit generalizations about biological, human, and social systems.

A concept of causality based on universal laws is pervasive in the sciences. Most philosophers of science have confined the enterprise almost entirely to the universalist framework, although, of course, exceptions exist.¹¹ We believe that epidemiologists among others have been misled by standard interpretations of the nature of science.

The search for universal laws of the material world must deal with a paradox. The smaller the interacting microcosmic elements that such laws explain, the more likely those elements are to be universal. Universality implies a view of space and time expanding outward across the boundaries and horizons of our world and others, unimpeded by the local accretions and characteristics of intervening structures such as planets, continents, or our biological world, including people.

Some laws may hold across our planet for species and the evolutionary processes that produced them. But above the level of molecules, no biological entity can conform entirely to universal laws because of the overarching contexts and the interactions between levels within a biological structure. And the banal fact is that each society is influenced by its economic, political, and cultural circumstances as well as by its mix of peoples, climate, and topography. What is most universal is least biological and, most of all, least human.

It follows that universalism is not universally applicable to the scientific endeavor. Thus, when we enter the physical, biological, and social realms of the human world, we need a parallel set of ideas interwoven with the search for generality. In epidemiology, the poor fit of universalism with human reality is better replaced by a contrasting construct of ecologism. Ecological constructs try to deal with the true complexity of the biological world. Such constructs must in varying degree be localized; they must be bounded if they are to encompass all of the biological world's less-than-universal levels and their particular interactions.

Chinese Boxes: A Paradigm for Eco-Epidemiology

In proposing a paradigm in the vein of ecologism, we draw on and develop an earlier formulation of agent and host esconced in an environment that comprises systems at multiple levels.⁴ Our concept envisages interactive systems. A system is a set or assembly of factors connected with each other in some form of coherent relationship. Thus, a system is an abstraction that allows a set of related factors to be described in terms of a coherent structure or coherent function. We speak properly of anatomical (structural) systems and physiological (functional) systems—circulatory, nervous, or reproductive. The human body is in itself a system that encompasses all these. Societies comprise much more complex systems of persisting and ordered relations. The universe is a system of vast scale, a molecule one of minuscule scale.

Each system can be described in its own terms. Each defines the limits of a particular level of organization and the structure within those limits. Hence, a set of factors that make up a system can be identified. Their coherence implies a degree of persistence and stability. This stability coexists, however, with the capacity for change. Because the factors contained in a system relate in some fashion, change and activity in one sector impinges on and affects other sectors.

Systems also relate to one another; they do not exist in isolation. A metaphor may serve to illuminate this ecological perspective. We liken it to Chinese boxes—a conjurer's nest of boxes, each containing a succession of smaller ones. Thus, within localized structures, we envisage successive levels of organization, each of which encompasses the next and simpler level, all with intimate links between them.

Within each level, a relatively bounded structure such as a nation or society or community may be characterized by lawful relations that are localized to that structure and can be discovered. At any given level within the hierarchy of scale and complexity, these lawful relations are generalizable, but only to the extent that they hold for other similar structures, whether they are societies, cities, local communities, or individuals.

The paradigm represented by the metaphor of Chinese boxes could be suited to a new eco-epidemiology (Table 1). This paradigm treats relations within

TABLE 1—Eras in the Evolution of Modern Epidemiology and an Emergent Era

Era	Paradigm	Analytic Approach	Preventive Approach
Sanitary statistics (first half of 19th century)	Miasma: poisoning by foul emanations from soil, air, and water	Demonstrate clustering of morbidity and mortality	Introduce drainage, sewage, sanitation
Infectious disease (late 19th century through first half of 20th century)	Germ theory: single agents relate one to one to specific diseases	Laboratory isolation and culture from disease sites, experimental transmission and reproduction of lesions	Interrupt transmission (vaccines, isolation of the affected through quarantine and fever hospitals, and ultimately antibiotics)
Chronic disease epidemiology (latter half of 20th century)	Black box: exposure related to outcome, without necessity for intervening factors or pathogenesis	Risk ratio of exposure to outcome at individual level in populations	Control risk factors by modifying lifestyle (diet, exercise, etc), agent (guns, food, etc), or environment (pollution, passive smoking, etc)
Eco-epidemiology (emerging)	Chinese boxes: relations within and between localized structures organized in a hierarchy of levels	Analysis of determinants and outcomes at different levels of organization: within and across contexts (using new information systems) and in depth (using new biomedical techniques)	Apply both information and biomedical technology to find leverage at efficacious levels, from contextual to molecular

and between localized structures that are bounded socially, biologically, or topographically. The appropriate epidemiological approach is to analyze determinants and outcomes at different levels of organization. Such contextual analysis would draw on new information systems both within and across levels to achieve breadth. It would draw on new biomedical techniques to achieve depth. The action that follows would need to find leverage at the most efficacious levels, whether contextual or molecular or both together.

The metaphor of Chinese boxes is perhaps not apt in every dimension, in that levels exist in a hierarchy not only of scale but also of complexity, with multiple interactions between and within levels.^{14,15} The outer box might be the overarching physical environment which, in turn, contains societies and populations (the epidemiological terrain), single individuals, and individual physiological systems, tissues and cells, and finally (in biology) molecules.

To study even ecological systems in depth, we still have to use the basic methodological procedures of science and limit the fields of observation. Epidemiology can never aspire to the reductionism that Freeman Dyson defines as the “effort to reduce the world of physical phenomena to a finite set of fundamental equations.”¹² Steven Weinberg calls this “grand reductionism,” which entails a view of nature. However, epidemiologists must of necessity live with and use what Weinberg calls “petty reductionism,” which entails only a research procedure or program.¹³

But these approaches should not be allowed to obscure the contextual structure of enveloping systems.^{14,15} To deal with such a hierarchy of enveloping systems, the need for a new paradigm is patent.

Choosing the Future

Although we hear stirrings, we have yet to adopt, develop, and apply this type of paradigm in epidemiology. What we present here is no more than a skeletal framework. As this embryonic paradigm is tested in the field, no doubt its simplifications and inadequacies will emerge, and some of its deficiencies will be repaired.

The paradigm is bound to evolve and change as the constraints of existing thought are broken, and one can expect it to confer new power on epidemiology. Such a paradigm will require a slew of sophisticated methods—borrowed, adapted, and created anew—that enable epidemiologists to test models at levels from the molecular to the social.

At this time, the task will seem daunting, even hopeless, to many of us. Few epidemiologists are equipped to undertake it. At the beginning of this century, however, Ronald Ross pioneered an analogous approach.¹⁶ In 1902 he won the Nobel prize for establishing (in the 1890s by painstaking microscopy) that mosquitoes transmit malaria. He thereafter took an epidemiological approach to eradicating the disease. Epidemiology and a mathematical bent led him to

multivariate modeling to determine what the efficacy might be of interventions of different sorts.

We draw further on historical precedent to justify optimism. A study of the literature of the early Chronic Disease era¹⁷ confirms direct experience of the elementary design and analytic tools in use at the opening of the era. Design principles were only just taking form, and multivariate analysis was almost inaccessible. The contrast with the powerful designs and sophisticated analyses of the latter years of the era could scarcely be greater. Many such precedents give us reason to believe that the requisite analytic tools are within reach, provided that the attention of epidemiologists is focused on their development and use.

Here one must recognize that a molecular paradigm taken on its own is hugely attractive because of its explanatory power. Without conscious countervailing effort, that paradigm will very likely come to dominate epidemiology no less than did the germ theory in its time. In that event, with the sacrifice of conceptual and analytic breadth, epidemiology could again be reduced to a derivative pursuit of laboratory science, and the mainstream of our subject could be lost to creative science. A countervailing force, which at the same time restores public health to epidemiology, resides in a developed version of the Chinese boxes paradigm.

One must also take heed of another emergent paradigm. Information systems combined with systems analyses might well lead into a systems paradigm, with its

own attractions for mathematically minded epidemiologists. Standing alone, this paradigm would sacrifice biological depth and the direct address to health disorders. To avoid constriction, both the emergent themes of biology and information as well as the black box of our era need to be subsumed into a broader paradigm such as the Chinese boxes proposed here for eco-epidemiology.

A cogent scientific paradigm alone is not enough to anchor epidemiologists to public health, however. So what more is needed to accomplish the linkage, one may ask, beyond simple evangelism for an epidemiology inviolably tied to the public health?

Socialization

At the least, a practical program must be devised to ensure that, in the course of their education, epidemiologists are socialized in a manner that keeps alive the idea of improving the public health as a primary value. Epidemiologists must be scientific but also in some degree professional in the sense traditional to medicine, the law, and the clergy. That is, society accords them a privileged and autonomous function founded on special training. That autonomy carries reciprocal and primary ethical obligations for service to individuals or society.

To maintain such an ethic, we shall have to choose and act accordingly. The power of the socialization process to imbue values is well documented in the work in medical education pioneered by Robert Merton and his colleagues¹⁸ and in much that followed.

In this respect, epidemiology and public health face ambiguities of role and status. As emphasized above, the public health function has been to serve populations and, informed by notions of social equity, to prevent and control disease in those populations. Yet the historic origins of epidemiology are predominantly if not exclusively in medicine. And for millennia, the medical function, enshrined in ethics and teaching, has been primarily to serve sick individuals.

In this century, epidemiology and public health have often withered in a medical environment that almost inevitably must give primacy to the individual care of sick persons who solicit care. It

follows that autonomous schools of public health among others can have a crucial role in socialization.

The diversification of public health professions has resulted in further role ambiguities. In addition to the doctors and sanitarians who were its original mainstay, the public health corps now comprises statisticians, economists, social scientists, professional administrators, organization and other specialists and epidemiologists without medical training. This diversification has centrifugal force. To imbue these diverse groups with the values of public health, schools of public health will have to give due weight to the process of socializing their students to common values.

Socialization of students to public health will require conscious induction through learning about its traditions and its history. They will need exposure to faculty and others who understand and embody public health values. They will need learning experiences in community situations as vivid and telling as those provided for medical students by clinicians at the bedside. They will need to comprehend the hurt and waste of deprived or disordered communities. They will need to recognize the true scale of the effects that a few percentage points in a cogent indicator can have on a nation's health.

Without intense socialization and learning, we may well find—because of the natural momentum and narrow focus that specialization generates—that the links between the values of public health and its specialized disciplines dissolve as we watch. In this respect, epidemiology is most certainly at risk. □

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