Man, Ecology, and the Control of Disease

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FROM ITS BEGINNING the field of public health has been concerned with man in relation to his environment and, in this sense, oriented toward concepts which were later subsumed under the terms ecology and human ecology. Today, interest in the reciprocal relationships between man and his environment has greatly broadened and intensified. Clearly, the solution of many emerging health problems will require greater knowledge of the balances and interactions involved. It is clear also that we must understand these relationships in their totality even though we may be obliged to dissect them separately. Sooner or later, we must somehow contrive to assemble them as a whole—the physical, the biological, and the social.

If such an endeavor falls within the province of any single field, it would seem to be that of human ecology. Accordingly, it is the purpose of this paper to explore some of the ways in which human ecology, as a system of thought, and public health, as a field of application, may be associated profitably.

Human Ecology

Since the sociologists, Burgess and Park, first introduced the term "human ecology" in 1921, there has been a rapid succession of adaptations of the term and concept of "ecology" to various disciplines concerned with the study of man. Students of sociology, geography, social anthropology, medicine, public health, economics, and even some highly applied fields such as business administration have all recognized to some degree the importance of ecological concepts and have tried to apply them.

The usual definition of ecology as the study of the relationships between organisms and their environments does not quite suffice in applying the term to man although etymologically it should do so. The reason lies in some uncertainty about what is meant by the word "environment."

The more specialized ecologies can generally restrict the ecosystem with which they are concerned to the immediate physical surroundings, and feeders into those surroundings, of normal or expected occurrence. Not so, the ecosystem of man. Man differs from other forms of life in several major respects that make his ecosystem difficult to define. His mental and physical capacities make it possible for him to draw upon an unknown and unmeasurable universe of physical and biological resources. He is neither an animal in a cage nor even a fish in a very large ocean. To be sure, he is bound to an environment that will supply his basic needs, but he has learned to modify or control his natural surroundings so successfully that he can live almost wherever he pleases. Also his capacity for adaption through social organization is certainly unique in degree if not in kind.

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Another major area of difference is in the existence and impact of man's aspirations, goals, and "inheritable" culture. These make life simpler for him in many ways, but they profoundly complicate it in others. While completely abstract in nature, they most certainly behave as environmental forces and must be given great weight in any consideration of ecology and health. Sometimes sociologists find it convenient to disregard such things as human purposes and values on the assumption that they will find tangible expression in some measurable institutional form or practice (*1*). But, as will be shown later, this is not always the case in matters affecting health.

The most vital concept that ecology can bring to our thinking is that of holism, the idea that man is a part of a comprehensive system of dynamic interdependencies (*2*). Yet, this is an extremely difficult concept to translate into operational form. It is too global and too abstract to find a useful place alongside our more tangible and commanding involvements with phenomena of a more immediate nature. It is tempting and convenient to simplify the study of man in his environmental relationships by some act of definition, choice, or arbitrary exclusion, but the fact remains that man gets to be what he is by the forgings wrought from his total environment and not from some part of it that may appeal to the specially oriented investigator.

Among the several functions of public health, prevention of disease is, without doubt, the function of the greatest ultimate value. (This practical emphasis on prevention is not intended to exclude the more positive functions of health promotion that the future may bring.) In the pages that follow I shall undertake to explore the preventive process in the perspective of ecology and, more particularly, of holism.

Causation and Prevention of Disease

In traditional epidemiology, disease causation is regarded as resulting from an interaction between a host (in this case man), an agent (such as a parasite), and the environment which brings the agent into effective contact with the host. Whether or not this epidemiologic triad should be regarded as an ecological concept depends upon the breadth with which it is applied. Certainly the pattern of the triad is consistent with ecological concepts, but for the purpose of disease control it can be employed effectively only in a very constricted sense that has little regard for ecology. As Dubos (*3*) has pointed out, tuberculosis could be completely controlled by elimination of the tubercle bacillus, which is the "causative agent," but the ecology of the clinical disease involves a great deal more than simple exposure to tubercle bacilli.

A more inclusive construct is represented in the formula (*4*):

Health status=*f* (genetic man, total effects of environment).

In other words, man's health status is a function of his heredity and the current and accumulated effects of his environment. The formula differs importantly from the epidemiologic triad in that it relegates the agent to a place among other components of the environment. Also it is consistent with an interpretation of the environment as being both material and nonmaterial.

The relationships are to some extent reversible; that is, man's environment is likely to be affected by his health status and perceptions of health need. This applies especially, of course, to his technology and institutions, but it may also apply to his material environment as he contaminates, erodes, controls, improves, or otherwise manipulates it.

If we accept the tenets of this formula, it is evident that disease may originate from defects in either the genetic potential of man or his environment, or both. It also follows that preventive measures might be focused in either direction.

Prevention and Man's Genetic Potential

We probably do not think of evolution as a preventive method but it obviously is. Many of the genetic characteristics of man today are the screenings of natural selection as it has reflected the possession or absence of traits which have enabled him to ward off the effects of disease. The sickle cell trait is a somewhat exotic but clear example. It is debatable whether this kind of selection may still be going on. Some biologists (*5*) claim that the impacts of man's cultural heredity and his elaborate technology have so overridden the biological process of natural selection as to make it virtually inoperative today. It is noted, for example, that in this country only a very small proportion of all female children born today will fail to outlive the normal reproductive period. On the other hand, conditions are not as favorable for a large part of the population of the world, or even in all parts of the United States.

It is a parenthetical but certainly relevant point that it was Charles Darwin who first laid the systematic basis upon which the German biologist Haeckel first used the term "ecology" in 1868. As noted by Hawley, "Scientific ecology, then, is indebted to Darwin for the main outlines of its theory, the essential conceptions being: (1) the web of life in which organisms are adjusted or seeking adjustment to one another, (2) the adjustment process as a struggle for existence, and (3) the environment comprising a highly complex set of conditions of adjustment" (*2*).

With respect to the preventive functions of public health, there is no reason why we should assume that all selective evolution has to be natural in the Darwinian sense. Indeed, cultural values are clearly expressed in the selectivity of mating, and opportunities for further influencing our genetic stock through eugenic practices are not at all remote. Equally challenging is the subject of environmental determination of genetic penetrance or the emergence of one genetic potential over another. This certainly is an area deserving of epidemiologic study as well as the "bench" research of the biologist.

Prevention and Man's Total Environment

It is a major assumption of ecology that all the elements of nature are interdependent—light, air, water, soil, vegetation, animals, and man. Over the various parts of the earth, whenever the basic physical elements have existed in a relatively stable relationship for a sufficient period of time, the biological elements have become established in food-chain and other dependency relationships. According to the characteristics of an area certain species have tended to become dominant and others subordinate, and ecological balance has been achieved through stabilized relationships or, in some cases, through slowly moving cycles.

During most of his million or so years on earth, man has had to survive much in the same way as all other forms of life, seeking to hold his own against the environment of which he was a creature but in no sense master. Then, almost precipitously, he made his breakthrough and in little more than 10,000 years he has done what no other living thing has ever done; he has become the master of most of his environment. This is a heady experience, and, as such experiences often are, it could be disastrous. Raymond Bouillenne states the case: "Man seems reluctant to accept his place in nature. He declares that the power of his genius, the vastness of his technical achievements, and the abundance of his populations place him beyond the limits of nature. He forgets that he is the outcome of a long series of evolutionary adjustments and that his ascendency over nature is recent indeed" (*6*). If man has put himself above nature, what does he propose to substitute for that which, for so very long, has been revered as the "wisdom of nature"? We in public health are accountable, I believe, for providing our part of the answer.

Since we must start somewhere, I suggest we start with the ecological axiom: The introduction of any major alteration in the balanced elements of an established ecosystem will necessitate adaptive responses to maintain that balance or else the character of the biological life supported by the ecosystem will change. It follows that each major alteration of the physical or biotic environments introduced by our technical way of life must be matched by appropriate offsetting or neutralizing mechanisms. Stated as a law of human ecology we may say, then, that survival in an increasing technology will be dependent upon still further increases in technology.

The implications of this suggested law may be alarming, but human ecology is not a palliative subject. In any given situation this law brings into immediate focus the problem of making the most effective choices among all possible neutralizing mechanisms or techniques, and it is at this point that man must learn to distinguish between decisions of expediency and decisions of long-range judgment. We are well experienced in the former. The wisdom for the latter can come only from a much better science of human ecology than we now possess.

Let us take a simple example. Radiation waste products present a great potential health hazard, and the only absolutely sure way to protect the public would be to prohibit their production. However, the economic complexities and disruptions would be so great that such action has never been considered seriously. Instead, an answer of expediency is being adopted by public health departments in their governmental roles, and planning is in terms of "tolerable limits" of atmospheric, food, and water contamination. An obstacle of some importance, of course, is that no one knows enough about the eventual effects of radiation on man or his ecosystem to supply a wholly satisfactory basis for establishing realistic protection guides or evaluating the risk that must be taken in the light of probable social or individual benefits. Many similar examples could be given, and such problems appear to be pyramiding.

Theoretically, we might hope to see prevention applied "across the board" so that each proposed new disruption of ecological balance would be thoroughly analyzed before it was undertaken and corresponding arrangements made to take account of it in the ecosystem. But this is plainly impossible. We possess neither the knowledge necessary for such decisions nor the political structure to activate them if we did. Moreover, I suspect that the implied ideal of a state of material and social equilibrium is incompatible with human nature in any case. So we shall have to seek a more realistic goal.

As I see it, our task is to keep from getting into irrevocable difficulties with our own short-range decisions while we acquire the wisdom and the means for making long-range ones. In other words, we need to keep ourselves in balance wherever we can while man learns to cope with the tremendous task of managing his newly acquired universe, hopefully before he destroys himself. One of our more serious problems is the tremendously increasing complexity of everything that we undertake. Specialization is both a cause and a consequence of this complexity, and we are getting our share of it in public health. Now, there is nothing inherently undesirable about specialization per se. Without specialization we should have advanced very little, but when it becomes excessive, it clutters the channels of communication, divides resources and scarce manpower skills, proliferates divisions, bureaus, units, and programs, builds little empires of interest, and so on. An even greater danger is that it might become a way of life in which the whole problem, the whole man, and the whole community are forgotten, and this could lead us astray in both our search for the causes of disease and our attempted programs for their prevention or control.

In suggesting that we try to gain new perspective by taking a careful look at our present specialized approach, I find comfort in the fact that I am in the good company of Leona Baumgartner, who recently expressed her concern over the fact that public health has become "a many splintered thing," and of Rene Dubos, who recently wrote, "But it seems to me that the law of diminishing returns is beginning to operate in this approach to the problems of infection. . . . I do question the magnitude of the beneficial effects that we can derive from these techniques with regard to the total disease problem in our communities today" (*7*).

In a strict sense the holism of ecology and the specificity of specialism appear to be antithetic, and I suppose they are. However, if we grant to holism the greater truth, we must concede to specialism the greater utility, at least with respect to its current usefulness in public health and medical science. Therefore, my advocacy of a modified approach to disease prevention, as suggested by ecological considerations, is presented with the conviction that I do not seriously threaten all that is going on. I believe there are grounds for experimenting along the lines I shall suggest, but I propose them as complementary to and in no sense as substitutes for many existing methods that have deservedly established themselves.

I shall present two "case studies": the first illustrates some interesting possibilities that arise from a nonspecific, ecologically oriented approach to the study of disease causation; the second presents evidence supporting a reconsideration of the generalized approach which characterized effective programs for the prevention of disease almost a century ago.

A General Approach to Disease Causation

CASE STUDY 1. A series of studies on the relationship between illness, life experiences, and the social environment was conducted by Hinkle, Wolff, and their associates at Cornell (*8*). The studies were based on retrospective and prospective observations of the members of several occupational groups, each of which was currently homogeneous in terms of the usual demographic criteria such as age, sex, ethnic background, and socioeconomic status. The health records of many of these people could be traced back as far as 20 years with remarkable accuracy owing to the unusual medical program of their employer. The records showed that in each homogeneous population group approximately 25 percent of the members experienced 50 percent of all of the known episodes of illness and another 25 percent had less than 10 percent of these episodes. (The presence of such an unequal distribution of illness among individuals and families has had considerable confirmation in studies such as those by Smiley and associates (*9*) and Densen and associates (*10*).)

This clustering of episodes of illness made it possible to select from within each homogeneous group two sharply contrasting subgroups, one with a high level of illness experience and the other with a low level. The individuals in these two subgroups were then subjected to exhaustive studies including a detailed life history, physical and psychiatric examinations, and observation of their health records and experience over varying periods of time. Certain differences were revealed in the backgrounds and habits of the individuals in the high and low subgroups in such things as marital status among women employees and smoking habits among the males, but the single, overriding variable which differentiated them was what Hinkle and Wolff described as "each individual's relation to his own life situation."

The measurement of such a variable is certainly difficult; however, these investigators had much experience to guide them. Furthermore, similar inferences have been drawn in a number of studies of different population groups and of population groups differently subdivided, such as the recent study by Christenson and Hinkle (*11*) which compared the illness experiences of managerial workers with and without college education.

The composite data of the series of investigations at Cornell further revealed that individuals who experienced a great many episodes of illness also experienced illnesses involving a number of body systems. As the amount of illness experiences by an informant increased so did the number of body systems involved. We should note that these studies were focused on episodes of illness of all kinds rather than episodes of a single, specific diagnosis. The target was general morbidity.

A study of this kind is exceptionally difficult to design and conduct, and I am aware of the criticism which this particular series has evoked. Whether the details of the findings are eventually confirmed or not is relatively unimportant to this discussion. The important contribution is the use of a method which was not committed to a preconception of specificity and which was broadly ecological in its approach. It dealt with whole persons, whole lifetimes, and whole ecosystems as nearly as it could. Also, the findings suggestive of a generalized causative factor illustrate a principle of method which may turn out to be very important.

The potential contributions of this method of studying disease causation are readily seen in the following hypotheses that may be built upon the findings of the studies at Cornell:

1. Illness experience appears to be more strongly related to some deeply underlying pattern of environmental relationships and adjustment than to the events which determine the specific organ system that will be involved or the type of illness which may appear at any given time.

2. The specific type of illness occurring in a given individual may be the result of events of a more or less circumstantial nature which would have little effect in the absence of an underlying, debilitated state.

3. General preventive measures directed at the determination and control of the underlying patterns of environmental relationships

will prove more efficient and effective in the long run than so-called specific measures.

These hypotheses appear to be far reaching—they even alarm me a little—but they are not unreasonable interpretations of the evidence. Also, they do not appear to be beyond the possibility of physiological support through extensions of the concept of homeostasis and the general adaptation syndrome. Actually, there is no prevailing reason why the concepts of specificity that apply to infectious diseases and in instances of physical or chemical insult should be carried over in an attempt to explain all morbid conditions similarly. If the concept of specificity is being mistakenly applied, the complications that it could throw in the path of our understanding of disease causation could be enormous.

But it is the methodology that concerns us here. If we are to assume that every disease is the result of a specific cause, then the method used by Hinkle and Wolff would be unnecessarily laborious and indirect. If, however, we are to allow the possibility that some underlying condition of general debility is basic to most illness, then any search limited to specific diseases or specific causes is likely to miss important relationships.

To explore this point further, let us look at the studies being conducted in the causation of coronary heart disease or of lung cancer. The great majority of such studies are designed in the accustomed way when one seeks to identify the role of a causative agent or chain of events with respect to a specific disease. The findings to date have been encouraging, and crude etiological models can be formulated which project the importance of certain environmental or somatic factors with some degree of predictability. But these models tend to be incomplete. For example, the evidence is strong for a causative relationship between cigarette smoking and lung cancer, but not all heavy cigarette smokers develop lung cancer nor do all patients with lung cancer have histories of significant smoking. Clearly, then, cigarette smoking is not a necessary cause of lung cancer nor is it a sufficient cause in many instances. In order to explain these inconsistencies we might postulate either that some as yet unidentified factor, which is highly but not exclusively associated with cigarette smoking, may be the necessary and sufficient cause or that lung cancer, as a response to environmental stimuli, may be far less specific than previous experience has led us to expect. It is particularly interesting to me to note that despite all the controversy over the issue of lung cancer and cigarette smoking nearly all the attention has been given to the first of these alternative explanations and almost none to the second.

The general failure to appreciate the possible importance of the second explanation may arise from the lack of a sufficiently recognized theoretical basis to support such an idea. It appears to me that this necessary theoretical basis can now be supplied.

A General Approach to Disease Control

CASE STUDY 2. The material for this study is to be found in Sigerist's translation and interpretation of Max von Pettenkofer's lectures on the "Value of Health to a City," delivered in Munich in 1873 (*12*).

When Pettenkofer was appointed the first professor of hygiene at the University of Munich in 1865, health conditions in that city were bad indeed. The general death rate was 33 per 1,000 population, sanitary conditions and housing were appalling, and industrial expansion was making matters worse. By way of contrast, Pettenkofer had before him the example of England. The first country to experience the ill effects of industrialization, England had also been the first to react against them, and the social reforms of the mid-19th century had put her far ahead of other countries in matters of health. In London, for example, the general mortality had dropped to the then remarkably low level of 22 per 1,000 population. The challenging question to Pettenkofer was whether Munich could be made as healthy as London.

Pettenkofer "was fully aware that man lives not only in a physical but also in a social environment. He saw that customs and habits have a great influence on health and must be investigated just as carefully as physical factors." Fortunately, Pettenkofer's views were heeded by the city fathers of Munich, and many social reforms were instituted at his suggestion.

Clean water was brought from the mountains, a new sewerage system was installed with outlets of carefully established safety, a new public slaughterhouse was built and food inspection was rigorously enforced, housing projects were launched, health commissioners functioned in every community, and it is to be supposed that there were other important changes in the manner of living.

These reforms were not all brought about at once. The first changes involved the sewerage system and the water supply, and these promptly brought about a reduction in the general death rate from 33 to 30. This was exactly what Pettenkofer had predicted on the basis of the English experience, and he had wisely forewarned the people of Munich that this was not the final goal. He continued to press for the remainder of his reforms, using London as his ecological model. By the turn of the century he had succeeded. The general mortality rate had been reduced to 22, and Munich could then be called the "healthiest city in Europe."

While other, intervening variables may have entered the picture during this 27-year period, it would be difficult to dispose of the convincing evidence that Pettenkofer had proved his hypothesis. The point of importance here is that he employed a nonspecific, ecological model, London, and he evidently had the wisdom to select a sufficient number of the right factors in his interpretation of that model. Of course, this method borrowed greatly from the wisdom of the past, for it had been amply demonstrated long before Pettenkofer's time that it was possible to reduce mortality from disease through social and sanitary reform aimed at some of the more obvious evils of urbanization and the industrial revolution. Such reforms were nonspecific and preceded the application of bacteriology and immunology to disease control. It may now be recognized that these early measures not only struck at the chains of transmission of disease-producing agents, but they also probably did much to improve the general level of nutrition and eliminated other factors which lowered the people's resistance to disease.

Viewed historically, Pettenkofer's success was one of the last and crowning demonstrations of the application of lessons derived from over a century of turbulent sanitary and social reforms. These reforms were not scientific but neither were they completely devoid of scientific substance. As early as the mid-18th century the growing scientific acumen that gave man the technology for the industrial revolution also gave him some of the observational basis for accurate appraisal of the social evils that it generated. So these general measures were often quite sound.

With the advent of scientific bacteriology and immunology in the last quarter of the 19th century, the interest and emphasis shifted rapidly to the concept of specificity, at least for the infectious diseases. And public health programs followed suit. Although they never completely abandoned the important gains brought by the earlier methods of environmental sanitation, they did lose sight of the general approach to a considerable extent. Whenever it became possible to deal with disease causation through the more or less direct methods supported by the doctrine of specificity, such methods increasingly became the ones of choice. Although many of these advances have been scientifically brilliant and successful, they have added further impetus to the proliferation of separate and specialized uses of our energies and resources already noted. This case study suggests that we might reduce the confusion and perhaps be more efficient as well as effective in our preventive programs if we could learn to see our ecosystem and its health problems in larger chunks rather than increasingly smaller ones. The Munich experience suggests that ecological models might be employed effectively, now as they were then, even though the exact etiological factors remain unknown.

The nature and the degree of contrast existing between London and Munich in Pettenkofer's time is not unique, and similar contrasts may be found between population groups today. For example, in the United States striking variations exist in the age-adjusted mortality experience among the States. In 1950 the age-adjusted mortality rate for the population of several of the midwestern agricultural States was in the range of 8.5–8.7 per 1,000 population, while that of a corresponding group of southeastern agricultural States ranged from 12.3–13.5. Corrections for racial distribution modify slightly but do not eliminate these differences. Moreover, they persist year after year and so far have not been satisfactorily explained. It seems reasonable to suppose that these differences hold important keys to a better understanding of conditions generally conducive to high or low levels of mortality. Meanwhile, such different areas stand available to us as contrasting ecological models much as London did for Munich in 1873.

Summary

This paper has undertaken to define and explore the holistic concept of human ecology in relation to both studies of disease causation and measures for the prevention or control of disease. The view is developed that man's ability to survive in the face of an ever-increasing technology will depend upon still further increases in technology in order to maintain essential ecological balances. Since today's technology is, by and large, one of increasing specialization, public health efforts are tending also to become more highly specialized. Although for the present these efforts are proving gratifyingly successful, they also are adding further complexities to an already overcomplex culture. Each new success appears but to add in some way to a series of new problems. The chain of proliferation seems endless, and the weight of the growing complexity in all that man must do becomes a mattern of concern.

The holism of ecology offers promise for the development of a new, unifying theory which may act as a counterbalance to the splintering effects of an otherwise rampant era of specialization. Because it focuses on underlying mechanisms and relationships, the application of ecological theory to public health practice may be expected to evolve methods that are highly efficient in terms of understanding and controlling conditions in man's total environment that are the major determinants of his health. Two examples illustrative of these potential effects are cited, one dealing with ecological studies of disease causation, the other dealing with program development in which the ecosystem is dealt with more or less as a whole.

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