THE DISEASES OF CIVILIZATION

RENÉ DUBOS

Each type of civilization has its own pattern of diseases. I shall focus my remarks on the health problems characteristic of the urban technologic environment, in the affluent countries that have adopted the ways of life now prevailing in Western civilization.

In affluent countries, as is well known, the expectancy of life *at birth* has rapidly increased during recent decades, but this achievement has not been accompanied by any significant increase of true longevity nor by a decrease in morbidity. I shall first discuss the paradoxical fact that despite medical progress, modern adults do not live longer and are not healthier than were adults at the beginning of the century.

In the past, a very large percentage of children died during the first few years of life, usually before the age of five; this is still true in most parts of the world, and in the underprivileged communities of the United States. In contrast, most children now survive into adulthood, wherever social conditions are favorable. The practical elimination of the nutritional and infectious diseases that used to be responsible for childhood mortality accounts for all the increase in the average expectancy of life *at birth*.

The life expectancy past the age of 45, however, has remained much the same for several decades. Furthermore, it is not greater in countries or social groups that can afford elaborate medical care than in underprivileged communities. This is because of the great number of deaths caused by disorders of the vascular system, various forms of cancers and, in general, the chronic and degenerative diseases that affect chiefly the adult population and for which there is no dependable method of prevention or cure.

My colleague Dr. Bruce Barron is presently engaged in an extensive and sophisticated statistical analysis of changes in death rates in large population groups for which reliable information is available (based on mortality statistics for New York City and from the National Center for Vital Statistics). His findings indicate that the expectancy of life past the age 45, far from increasing, has reached a plateau and may be actually decreasing as a result of *increasing death rates for specific causes* in this age cohort. Unfortunately, Dr. Barron's study is not yet ready for publication. For this reason I shall mention a few amateurish computations of mine that are in agreement with his findings and that may acquire a special interest from the fact that they deal with specialized professional groups, who report the obituaries of their members in scientific journals.

I have undertaken a comparison of age of deaths past the age 30 in four different human groups, who belong to privileged social classes, namely:

(a) Physicists, chemists and biologists whose deaths have been reported in the journal *Science* during the past three years.

(b) Physicists, chemists and biologists who died between 1850 and 1900.

(c) Physicians whose deaths have been reported in recent issues of the *Journal of the American Medical Association (JAMA).*

(d) Physicians who died between 1850 and 1900.

The preliminary computations based on some 800 entries for each of the four categories indicate that the percentage of deaths between age 30 and 60 is very much higher among scientists and physicians recently listed in *Science* and *JAMA* than among the groups for the years 1850–1900 (See Table 1).

A cursory sampling of a few old cemeteries in New York State and in the Pennsylvania Dutch country also suggests that longevity—as defined by expectancy of life past the age 30—was higher during the eighteenth and nineteenth centuries among the general population than it is today among scientists and physicians, and yet scientists and physicians, because of their position and occupation, can be presumed to have ready access to medical care! Modern medicine has little to offer for the prevention or treatment of the chronic and degenerative diseases that dominate the pathologic picture of modern technologic societies.

We are still much in the dark concerning the precise etiologic

TABLE I. DEATHS AMONG PHYSICISTS, CHEMISTS, BIOLOGISTS AND PHYSICIANS AFTER AGE 30

Age Group	*Deaths for 1850–1900 Physicists, Chemists Biologists and Physicians*	*Deaths for 1966–1969 Physicists, Chemists Biologists (from Science)*	*Deaths for 1966–1969 Physicians (from JAMA)*
	%	%	%
30–40	1.3	2.5	2.9
41–50	6.1 } 23.5	9.7 } 30.1	9.9 } 36
51–60	16.1	17.9	24.0
61–70	28.4	27.4	19.7
71–80	28.9	23.5	22.1
81–90	16.1	16.0	18.2
91 +	3.1	2.9	3.2

mechanisms of chronic and degenerative diseases, but there is no doubt that many of them are caused by environmental and social influences that affect most human beings in affluent societies.

A few months ago a symposium was held in Aberdeen, Scotland, on a similar topic, "The Biology of Affluence." Affluence was defined as "that state of societies or individuals in which materials and facilities are available in excess of those necessary for the maintenance of physical and psychological health." The urban technologic environment, however, has general pathologic effects that are almost independent of the economic affluence of its individual members.

Although there is no convincing evidence that physical and mental health need be impaired by urbanization and industrialization, the urban experience of mankind is so limited that a final judgment of the issue is not yet possible. Man has lived in cities, even in crowded ones, ever since Neolithic times; but until recently the urban population was constantly being renovated by the influx of nonurban people immigrating from primitive areas and rural environments. If present trends continue, however, the whole world will be urbanized and this biologic transfusion will no longer be possible. In the very near future, most children of city dwellers will be born, will develop and will raise their own children in urban environments. There is no way to foresee the long-range biologic and social consequences of urban life continued uninterruptedly for several generations.

Urban life exists in many different forms. One extreme is found in the compact cities of continental Europe—such as Paris, Hamburg, Milan or Athens—where most people live in apartments. Another ex-

treme is found in the sprawling agglomerations such as Los Angeles, Houston or Sydney, where most people live in detached houses. But granted that living in a compact city differs in many respects from living in a sprawling agglomeration, all urban environments impose on human life certain common characteristics that are determined by technologic forces over which man has little control.

Judged from the physical appearance and behavior of people in Westernized countries it would seem that most human beings readily make a successful adjustment to the new ways of life created by urbanization and industrialization. Yet the demand for medical care and for hospital facilities is constantly increasing in all Western countries. One of the reasons for this increased demand is that modern man has become more exacting with regard to health, and less willing than his ancestors to accept infirmities, pains and blemishes. A more important reason, however, is that increasing numbers of persons suffer from chronic ailments—both physical and mental—that do not necessarily destroy life, but spoil its later phases.

I shall now consider a few biologic aspects of the urban technologic environment that have interfered with the increase in true longevity and that contribute to the fact that we are as much as ever a disease-ridden society.

BIOLOGIC MANIFESTATIONS OF THE URBAN-TECHNOLOGIC ENVIRONMENT

Nutrition

Gross malnutrition used to be common among urban dwellers in the past, but this is no longer the case in prosperous countries. The city dweller may even enjoy some advantage over the farmer from the nutritional point of view, because the foodstuffs available to him throughout the year are commonly more varied and fresher than those found in country stores. But new dangers are created by the fact that appetites that evolved to meet our ancestors' physiologic needs can now be satisfied with much less physical effort and often to excess.

Unfortunately, little is known of the kind of nutrition best suited to modern urban life. Nutritional requirements were determined two generations ago for vigorous and physically active young men. These requirements certainly do not fit automated, air-conditioned life. Much remains to be learned also concerning the needs of the mother during pregnancy, and of her child during early postnatal life. Many

pediatricians are beginning to wonder whether the big baby is necessarily a healthy baby. Too generous a nutrition during early life may so imprint the child that his nutritional demands remain excessively large thereafter—with undesirable physiologic and behavioral consequences.

Environmental Pollutants

Most forms of environmental pollution, including noise, are universal in industrialized countries and are often at their worst outside the city —for example, on heavily traveled highways or on bodies of water crowded with motorboats. Sewage, organic chemicals and mineral fertilizers such as phosphates and nitrates pollute not only city reservoirs but also all natural waterways and lakes. Exhausts from automobiles, factories and incinerators are incorporated in smogs that are almost as intense over suburbs as over compact cities, and are progressively spreading all over the land.

No systematic studies have been made concerning the biologic activities of the various kinds of air and water pollutants. Very little attention, for example, has been paid to the colloidal material released from automobile tires, or to the asbestos particles released from brake linings and from materials used for insulation by the building trade. Yet these particulate materials constitute a very large percentage of the total mass of air pollutants, and are of a size that allows them to reach deep into the pulmonary tract. Because most kinds of environmental pollutants produced by modern technology did not reach significant levels until one or two decades ago, the worst effects of pollution are yet to be recognized.

It is becoming apparent, in particular, that ionizing radiations may not be the only, nor even the most important, of the mutagens to which we are exposed in the course of daily life. Many of the new chemicals that are widely used are likely to produce adverse genetic effects in man as shown in the recent report of a NIH genetic study (Crow, 1968). Even common substances, such as mercury compounds, have mutagenic properties at concentrations found in certain polluted environments, for example in Sweden and Japan.

Disturbance of Biologic Rhythms

The disturbances of biologic rhythms resulting from the modern ways of life may have deleterious effects on human health. Every person shifted from day to night duty or vice versa is aware of the

difficulties resulting from hormonal misadjustments that such shifts entail. Similarly, every traveller has experienced the physiologic discomfort associated with travel by jet aircraft from one continent to another. Bright illumination late into the night and uniform temperature maintained throughout the year by air-conditioning unquestionably contribute to comfort and increase efficiency. But it may turn out that these advantages will have to be paid for later in the form of pathologic effects yet to be determined because they have not been looked for. Grave pathologic effects have been demonstrated in chickens exposed throughout the year to artificial light for increasing egg production, and in frogs manipulated at different periods in their biologic cycles. But hardly anything is known of the effects produced on man by disturbances of his normal physiologic rhythms.

Crowding

Along with environmental pollution and noise, crowding and its consequences are aspects of city life to which objections are most commonly voiced. The fact is, however, that countless human beings appear to have elected to live among crowds throughout history, and even in prehistory. The Neolithic settlements, Rome during the Imperial period, the medieval fortified towns and the cities of the industrial revolution all exhibited population densities that have not been exceeded in our own times. Modern cities are larger, but generally less crowded than those of the past. Hong Kong and Holland are among the most crowded areas of the world, yet their populations enjoy good physical and mental health because they have slowly developed in the course of centuries patterns of human relations that minimize social conflicts and allow persons to retain their identity and a large measure of individual freedom. This does not mean that man can indefinitely increase the density of his populations, but only that the safe limits have not yet been determined.

The physiologic and behavioral disturbances observed in crowded animals and described by J. Calhoun under the name "behavioral sink" may occur in crowded human beings who have not yet become adapted to high population density (see later).

Change per se

One of the difficulties in the etiologic analysis of the diseases of civilization is that many changes in the surroundings and ways of life occur simultaneously and so rapidly that their individual pathologic

effects cannot be determined. Furthermore, change per se often acts as a pathologic agent, irrespective of the nature of the conditions that are changed.

In many cases, for example, the deleterious effects of crowding result not so much from high population density as from the social disturbances associated with *sudden* increase in density. The appalling amount of biologic and mental disease during the industrial revolution had several different causes, but one of the most important was certainly the fact that immense numbers of people from rural areas had to live and function in the crowded tenements and industrial settlements of the mushrooming cities before they had had time to make physiologic and emotional adaptation to their new ways of life. Yet, it took but a few decades to convert these rural populations into urban ones for whom high population density became almost a pleasant state of affairs.

In contrast, rapid decrease in population density, as is occurring at present in several states of North America, may increase the incidence of mental disorders. The rapid mobility of populations from one area to another is also contributing at present to the patterns of diseases in technologic societies.

EARLY INFLUENCES

The responses to environmental stimuli made by the organism during the very early phases of its development, including the intrauterine phase, deserve special emphasis because they exert profound and lasting effects on the physical, physiologic, and behavioral characteristics of the adult. Indeed, such effects often appear irreversible.

The following are a few of the many observations made in laboratory animals and that exemplify the remote and indirect manifestations of early influences.

A single exposure of young female mice to a small dose of radiation (25 r) does not destroy their fertility, but it shortens their reproductive lifespan by inactivating some of their oocytes in immature follicle stages. Because a long-delayed effect on fertility can thus be traced to oocyte damage occurring 24 hours after irradiation, there is reason to believe that other complex late effects may also be the indirect consequences of other types of cell death occurring immediately following radiation.

A single injection into neonatal mice of particulate pollutants com-

mon in urban air produces a high incidence of hepatomas much later during the adult life of the treated animals.

Subclinical infections contracted at birth, and mild nutritional deficiencies during gestation or lactation, have been found to depress growth rates and adult size in various animal species, even if the subsequent conditions were optimum for adult requirements. Many different types of stimuli that impinge on the organism during its early formative stages (even *in utero*) can likewise affect the learning ability and behavioral patterns of the adult.

ADAPTIVE RESPONSES AND THEIR FAILURES

The history of mankind demonstrates that most human beings can make biologic and social adjustments that enable them to adapt and continue to function effectively even under extremely stressful conditions. Paradoxically, however, the very fact that man is capable of achieving some form of adaptive response to many different kinds of stress accounts for many of his most serious medical problems.

The phrase "adaptive response" is convenient to discuss the interplay between man and his environment, but the notions of adaptation developed by biologists are not entirely suitable to the analysis of human medical problems.

The general biologist usually defines the word adaptation in Darwinian terms. For him, the word implies a state of fitness to a given environment, enabling the species to multiply and to invade new territories. In this light, man is remarkably adapted to life in highly urbanized and industrialized societies, as shown by the fact that his populations continuously increase and that he spreads urbanization and industrialization to more and more of the earth. It is obvious, on the other hand, that further population increase has become objectionable, and may soon become catastrophic. In applying the idea of adaptation to man, it is therefore necessary to use criteria different from those used in general biology.

Physiologists or psychologists give to the word "adaptation" a meaning different from that implied in Darwinian population theory. But their interpretation also fails to take into account the peculiarities of human life.

For physiologists and psychologists, a response is adaptive when it enables the person to maintain homeostasis through metabolic, hor-

monal or mental processes that tend to correct the disturbing effects that environmental forces exert on the body and the mind. Such adaptive responses contribute to the welfare of the organism at the time they occur, but unfortunately they often have secondary effects that are deleterious at a later date. When evaluated over man's whole life span, homeostatic mechanisms are less successful than commonly assumed because many, if not most, chronic disorders are the secondary and delayed consequences of adaptive responses that were useful at first, but are faulty in the long run.

It has long been recognized, of course, that homeostatic mechanisms can lead to unhomeostatic effects. This is particularly true when the homeostatic response is excessive. In traumatic shock, for example, intense vasoconstriction is homeostatic to the extent that it preserves blood pressure, but it is unhomeostatic at the same time because it deprives organs and tissues, such as the kidney, of their vital blood flow. In the hypervolemia of heart failure, the congestive state is useful up to a point in filling a weakened heart chamber, but leads ultimately to total failure by way of both excessive vascular pressures and overdilated heart chambers. As to the inflammatory reaction, it helps in fixing or destroying the aggressive agent, but it can in many ways destroy the organ while attempting to protect the body.

Most important, as already mentioned, is the fact that homeostatic mechanisms commonly have delayed and indirect consequences responsible for the pathology of many chronic disorders. The production of scar tissue is a homeostatic response because it heals wounds and helps in checking the spread of infection. But fibrosis in the liver or in the kidney means cirrhosis or glomerular nephritis; scar tissue may freeze the joints in rheumatoid arthritis or may choke the breathing process in the lung.

Many other examples readily suggest themselves, such as the various forms of hyperimmune response and the so-called compensatory reactions such as compensating polycythemia or compensating emphysema. These processes exert a protective or reparative function when they first occur, but they can become destructive in the long run. All too often the wisdom of the body is a very short-sighted wisdom. Jean Oliver stated this problem clearly in his discussion of acute tubular necrosis of the kidney: "The majority of the fatalities, in fact, occur during the 'recovery period,' as a result not so much of the processes of renal damage as of the mechanism of renal repair."

Maladaptive Responses to Pollution

Atmospheric pollution provides striking examples both of man's ability to function in a biologically undesirable environment, and of the dangers inherent in this adaptability.

Ever since the beginning of the industrial revolution, the inhabitants of Northern Europe have been heavily exposed to many types of air pollutants produced by incomplete combustion and the fumes from chemical plants; such exposure is rendered even more objectionable by the inclemency of the Atlantic climate. Long experience with pollution and with bad weather has resulted in the development of physiologic reactions and of living habits that have adaptive value, as proved by the fact that Northern Europeans accept almost cheerfully their dismal environment. Such adaptive responses to pollution occur all over the world in the heavily industrialized areas where people function effectively despite the almost constant presence of irritating substances in the air they breathe.

Unfortunately, the respiratory tract continuously registers the insult of the various air pollutants, even among persons who seem almost unaware of the smogs surrounding them. As a result, chronic pulmonary disease now constitutes the greatest single medical problem in Northern Europe. It is increasing in prevalence at an alarming rate also in North America, and it will probably spread to all areas undergoing industrialization. There is evidence, furthermore, that air pollution increases the incidence of various types of cancers as well as the numbers of fatalities among persons suffering from vascular diseases. But the long and indefinite span of time between cause and effect makes it difficult to establish convincingly the etiologic relations.

The delayed effects of air pollutants constitute models for the kinds of medical problems likely to arise in the future from other forms of environmental pollution. Wherever convenient, chemical pollution of air, water and food will be sufficiently controlled to prevent the kind of toxic effects that are immediately disabling and otherwise obvious. Human beings will then tolerate without complaints concentrations of environmental pollutants that do not constitute such a serious nuisance as to interfere with social and economic life. But continued exposure to low levels of toxic agents will eventually result in a great variety of delayed pathologic manifestations that will not be detected at the time of exposure, and may not become evident until several decades later.

Maladaptive Responses to Malnutrition

Adjustment to the various forms of malnutrition also has distant consequences of far-reaching importance. For example, persons who have been born and raised in an environment where food intake is quantitatively or qualitatively inadequate seem to achieve a physiologic adaptation to the kind of malnutrition that they have experienced in youth. Such adaptation, however, creates a vicious circle of metabolic difficulties and mental retardation or indolence. Similarly, children fed diets that are excessively abundant and rich tend to become large eaters as adults and thus may become more prone to vascular diseases.

Maladaptive Responses to Infection

As a result of the erronous belief that microbial diseases have been "conquered" there is a tendency to regard the so-called "minor" infections as inconsequential problems. Yet these ailments erode the functional integrity of the body, progressively damaging the respiratory, digestive and urinary tracts, as well as the kidneys and perhaps also the blood vessels. Like other stresses to which man becomes adjusted, minor infectious processes probably play a part in the diseases of the modern world.

Maladaptive Responses to Crowding

Man is a gregarious animal; he generally tends to accept crowded environments and even to seek them. Constant and intimate contact with hordes of human beings has come to constitute the "normal" way of life. This change has certainly brought about all kinds of phenotypic adaptations to social environments that constituted biologic and emotional threats in the past. But the long-range consequences of this adaptation are not known. If constant and extreme crowding has pathologic effects, these will have an insidious course, their expressions being determined not so much by the initial effect of the stimulus on a particular target organ, as by the complex secondary responses evoked from the whole organism and from the whole social group.

SHIFTS OF EMPHASIS IN MEDICAL RESEARCH AND PRACTICE

The physicians and medical scientists of the late 19th and early 20th centuries proceeded on the assumption that most disease problems originate from poverty and filth and therefore can be solved by im-

proving living conditions. This hypothesis placed the war against microbes and malnutrition at the center of the medical stage. The dramatic fall in mortality rates all over the Western world leaves no doubt as to the efficacy of the attack against the infectious and nutritional diseases that dominated the medical picture after the first industrial revolution.

Around the turn of the century the focus of medical interest shifted from the environment to the intimate structures and mechanisms of living organisms. Studies on the spread of infection or of the quality of foodstuffs lost ground to the chemical analysis of immunologic processes, of intermediary metabolism or of endocrine control. Even the Pavlovian reflexes and Freudian complexes are beginning to appear old-fashioned when compared with the detailed analysis of neural mechanisms or of memory storage and retrieval.

This change of scientific focus has had large practical consequences. Whereas the greatest contributions to health during the 19th century have been in the prevention of disease through manipulation of the environment, the most brilliant successes of 20th century medicine have been in the treatment of disease through action on the intimate mechanisms of the body. The 20th century can of course boast of spectacular feats in the prevention of disease, but these achievements have come in all cases from the direct application of 19th century ideas. For example, the development of new vaccines against bacterial and viral infections did not depend on knowledge of body structures or functions. The 20th century achievements in immunization were the fruits of theories developed and successfully used by 19th century immunologists. Similarly, the virtual elimination of deficiency diseases was achieved through nutritional improvements that were little influenced by knowledge of the precise role played by vitamins or amino acids in metabolic, synthetic or regulatory processes. The use of insulin and other hormones, the dietary control of phenylketonuria, the maintenance of normal physiologic processes during surgical interventions, the operation of artificial kidneys or of cardiac pace setters, are but a few examples of therapeutic procedures that could not have been developed without a detailed knowledge of body components and functions. There is even hope that some of the mental disorders can be managed through this approach.

The description of the organism in terms of its elementary structures and mechanisms, and the doctrine of specific etiology have led to such

spectacular achievements, both theoretical and practical, that it would seem sufficient to let medicine continue along the road on which it is now traveling to create a medical utopia. Yet, there are signs that a change in direction is necessary, and indeed is about to be made.

The disorders of the body and of the mind are to a very large extent the consequences of inadequate responses to the environment. They involve not only a particular organ, but the organism as a whole. Of special importance is the fact that the patient's responses are conditioned by past influences, especially the influences exerted by the factors that affected his early development. One of the greatest contributions of the Hippocratic school, and in our own times of Freud, has been to emphasize the importance of taking a "history" in the examination of the patient. History-taking will certainly become an even more important aspect of medical care in the future, when more is known of the extent to which the experiential past can affect all aspects of life.