

# **Our Synthetic Environment**

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# CHAPTER ONE: THE PROBLEM

## Our Changed Environment

Life in the United States has changed so radically over the past one hundred years that the most wearisome historians tend to become rhapsodic when they describe the new advances that have been made in technology, science, and medicine. We are usually told that early in the last century most Americans lived heroic but narrow lives, eking out a material existence that was insecure and controlled by seasonal changes, drought, and the natural fertility of the soil. Daily work chores were extremely arduous; knowledge, beleaguered by superstition, was relatively crude. Historians with an interest in science often point out that medical remedies were primitive, if not useless; they may have sufficed to relieve the symptoms of common diseases, but they seldom effected a cure. Life was hard and precarious, afflicted by many tragedies that can easily be avoided today.

In contrast with the men of the last century, men today, we are told, have developed nearly complete control over the natural forces that once were the masters of their ancestors. Advances in communication have brought knowledge and safety to the most isolated communities. The most arduous work has now been taken over by machines, and material existence has become secure, even affluent. Common illnesses that once claimed the lives of millions are now easily controlled by a scientific knowledge of disease, effective drugs, new diagnostic devices, and highly developed surgical techniques. The American people, it is claimed, enjoy more leisure, better health, greater longevity, and more varied and abundant diets than did their forebears a hundred years ago.

On the face of it, these statements are true, but by no means are all the advances as beneficial as the historians would have us believe. Recent changes in our synthetic environment have created new problems that are as numerous as those which burdened the men of the past. For example, soon nearly 70 per cent of the American population will be living in large metropolitan centers, such as New York, Chicago, and Los Angeles. They will be exposed in ever-greater numbers to automobile exhausts and urban air pollutants. Perhaps an even larger percentage of the employed population will be working in factories and offices. These people will be deprived of sunlight and fresh air during the best hours of the day. Factory and office work, while less arduous than in the past, is becoming more intensive. Although the working day early in the last century was very long, "the worker worked comparatively slowly, and both the employer and employee gave relatively little thought to productivity." Today, employers require a greater output per hour from each worker. The use of machines tends to make work monotonous and sedentary, often exhausting human nerves as completely as manual work exhausted human muscles. Modern man is far less physically active than his forebears were. He observes rather than performs, and uses less and less of his body at work and play. His diet, although more abundant, consists of highly processed foods. These foods contain a disconcertingly large amount of pesticide residues, coloring and flavoring matter, preservatives, and chemical "technological aids," many of which

may impair his health. His waterways and the air he breathes contain not only the toxic wastes of the more familiar industries but radioactive pollutants, the byproducts of peacetime uses of nuclear energy and nuclear weapons tests.

With the rise of these problems, dramatic changes have occurred in the incidence of disease. In 1900, infectious diseases, such as pneumonia, influenza, and tuberculosis, were the principal causes of death. Death from heart disease and cancer occupied a secondary place in American vital statistics. Fifty years later, mortality rates from infectious diseases had declined to a fraction of what they had been, but the percentage of deaths from heart disease and malignant tumors had more than doubled. It is very difficult to obtain reliable comparative statistics on the incidence of chronic, or persistent, diseases, but we can regard it as almost certain that the proportion of chronically ill individuals in the American population has increased. In any case, millions of Americans today suffer from major chronic disorders. Nearly 5 million people are afflicted with heart disease; another 5 million have high blood pressure. More than 12 million suffer from arthritis, 4 million from asthma, and at least 700,000 from cancer. Additional millions suffer from diabetes, kidney disease, and disorders of the nervous system.

Because many of these illnesses claim the lives of elderly people, we tend to associate chronic diseases with the aging process, and we usually explain their widespread occurrence by the fact that people are living longer. Men must die of something. With a reduction in the number of deaths from tuberculosis, influenza, and childhood infections, the diseases of aging people, it is claimed, should be expected to dominate our vital statistics. But are these diseases strictly products of the aging process? Do we have any evidence that they arise from basic physical disturbances peculiar to senescence? The answer is almost certainly no. Many disorders which afflict young people are precisely those so-called "degenerative diseases" that physicians and laymen associate with the retrogressive physical changes of old age.

Consider the age distribution in the incidence of cancer. Although many types of cancer are found mostly after the fourth or fifth decade of life, a surprisingly large number of varieties occur most frequently in childhood, youth, and early maturity. Cancers of the kidney and the adrenal glands usually appear before the age of four. Bone cancers reach their highest incidence in the ten-to-twenty-four age group. Malignant tumors of the testes usually occur in infancy and at maturity. So deeply entrenched was the notion that malignant tumors are diseases of elderly people that for many years physicians often discounted early symptoms of certain cancers in children. We now know that cancer in children occurs in nearly all the major physical organs of the body.

Today, cancer is second only to accidents as a leading cause of death in American children over one year of age. Although mortality rates for childhood cancers fluctuate from year to year, they have moved in a decidedly upward direction over the past two decades; for American children under fifteen years of age, they rose 28 per cent between 1940 and 1955. In 1959, cancer claimed 4100 lives and accounted for 12 per cent of all deaths in children between the ages of one and fourteen. These statistics make it hazardous to say that the illness is essentially part of the aging process. Strong reasons exist for suspecting that environmental factors contribute significantly to increases in death from cancer among young people.

The same suspicions can be extended to heart and vascular disorders. Until recently, heart disease in young people was caused primarily by infectious illnesses. Rheumatic heart disease, following streptococcal infections, claimed the lives of many children between the ages of ten and fourteen. Fortunately, the incidence of rheumatic fever has been reduced dramatically by the

use of antibiotics. On the other hand, coronary heart disease was generally regarded as a typical degenerative illness of older people, attributable to the onset of vascular disorders well beyond the peak of life. The disease seemed to be a culmination of the aging process. This view, too, is no longer a deeply entrenched medical opinion. Atherosclerosis, the precursor of coronary heart attacks, is not a universal feature of old age. On autopsy, many an octogenarian has been found to have coronary arteries that a man in his forties would be fortunate to possess.

Even more disconcerting is the unexpectedly high incidence of coronary illness now known to exist among young people. During the Korean War, the U. S. Armed Forces Institute of Pathology performed a series of autopsies on the bodies of 300 American soldiers, most of whom had been killed in front-line areas. Careful attempts were made to exclude cases in which there had been clinical evidence of coronary disease. The investigators, Enos, Holmes, and Beyer, observed that the average age in "200 cases was 22.1 years. The ages in the first 98 cases were not recorded except that the oldest patient was 33... In 77.3% of the hearts, some gross evidence of coronary atherosclerosis was found."

In at least 12 per cent of the hearts, the obstruction of one or more major coronary arteries exceeded 50 per cent of the arterial passageway. These are extremely high figures for young men who presumably were qualified for military service. A comparative study performed on the bodies of 350 Americans in Boston and 352 Japanese in Fukuoka "disclosed a considerable difference in the severity of coronary atherosclerosis" between the two national groups. In the American group every individual had some degree of atherosclerosis by the second decade of life, whereas Japanese could be found without the disease in the fifth and sixth decades. Comparing the extent of the arterial surface involved and the severity of the lesions found in the two groups, the investigators emphasize that "there was at least a two decade difference in the progression of atherosclerosis. The average American of age 40 and the average Japanese of age 60 presented comparable arterial disease."

In all probability, data of this sort merely supply us with fragmentary evidence of the extent to which chronic and degenerative illnesses are invading the younger age groups of our population. Many individuals seem to be succumbing to degenerative diseases long before they reach the prime of life. Not only is cancer a leading cause of death in childhood and youth, but the results obtained by Enos and his coworkers suggest that many American males between twenty and thirty years of age are on the brink of major cardiac disease. Although most of these individuals are likely to exhibit no clinical symptoms of vascular disorders-indeed, they would probably be regarded as healthy in routine medical examinations - it is reasonable to say that they are ill. If diseases of this kind represent the normal deterioration of the body, then human biology is taking a patently abnormal turn. A large number of people are breaking down prematurely.

Heredity, of course, may "play a role" - to use a well-worn qualification. But medical history warns us that genetic explanations of disease, particularly common diseases that afflict large sections of the population, are often a refuge for incomplete knowledge. Many such explanations are being contradicted by research. For example, it is very doubtful whether the "inherently" weak and sick, who presumably were rescued by modern medicine from the fatal infections of the past, are destined to be victims of cancer. In fact, there is good reason to believe that the body's mechanisms for resistance to cancers are entirely distinct from those that combat infections. ("The old idea that chronic diseases are 'degenerative,' or inevitable concomitants of aging," observes Lester Breslow, of the California State Department of Public Health, "is giving way to the modern idea that the origins of chronic disease lie in specific external causes which

can be discovered and thus controlled.”) With all due respect to genetics and to theories that attribute chronic disease to senescence, it would be more rewarding to examine the changes that have occurred over the past half century in man’s diet, habits, forms of work, and physical surroundings.

Terminal cancer patients, whose initial resistance to experimental inoculations of cancer cells is virtually nil, may nevertheless offer marked resistance to harmful bacteria and viruses. A team of Sloan-Kettering researchers inoculated fifteen terminal cancer patients with live cancer cells and germs. Thirteen patients showed no resistance to the cells, which took root and formed vigorous cancers. This will not ordinarily occur in individuals who do not have cancer. But the same cancer patients produced effective antibodies against inoculations of disease-causing bacteria and viruses.

## **Environment and Illness**

A balanced attitude toward environmentally induced illness has generally been the exception rather than the rule. In the past, as medical fashions changed, opinion would tend to swing from one oversimplification to another. For a long time, the germ theory of disease discouraged giving serious attention to the environment as a major factor in illness. Attempts to investigate the relationship between environmental change and disease were viewed as a regression to the pre-Pasteur days of medicine. The goals of research, it was declared, are to discover and destroy the microorganisms that cause illness. The physician was conceived to be locked in a struggle with microbes, and the human organism was regarded as virtually the only legitimate arena for waging this conflict. The synthetic and social environments outside man’s body seemed irrelevant to the basic problems of diagnosis and therapy, except where sanitation and the isolation of individuals with communicable diseases were involved. (In a brilliant survey of this period, Iago Galdston observes that as late as the 1920’s “few among the medical leaders gave much consideration (other than isolation, sterilization) to the ‘conditions of person and environment’ that favored the agents of infection. The attitude of the medical profession and of the public health workers was well reflected in the campaign slogans forecasting the stamping out of this or that infectious disease by the end of some ten, fifteen, or twenty years. The talk was of war, and the enemy was the tubercle bacillus, the gonococcus, the spirochete!”)

This view has never fully explained society’s experience with tuberculosis. In Europe, tuberculosis had always flourished among the urban poor, but except for occasional flare-ups here and there, the disease had never assumed the epidemic proportions of cholera and typhus. With the Industrial Revolution, however, tuberculosis became especially widespread and virulent. The crowding of uprooted rural folk into cities, the impoverishment and overcrowding of the new industrial laboring classes, and the decline in nearly all standards of nutrition, health, and sanitation raised tuberculosis from a tenacious but controlled urban disease to an illness pandemic throughout the Western world. The disease did not begin to recede until sweeping reforms were made in the economic life of Europe and America. It was brought under control only after the working classes had achieved shorter working hours, higher income, better housing, and improved sanitation - in short, after the standard of living had been raised. It is no overstatement to declare that the social reformers who were instrumental in getting children removed from

the factories and helped bring about higher wages and the eight-hour working day did more to control tuberculosis than did Koch, who discovered the tubercle bacillus.

When it became evident that the incidence of tuberculosis could be attributed to social factors as well as to the presence of a germ, another oversimplification took hold in medical circles. The disease was transformed into a model of environmentally induced illness. In respiratory tuberculosis, a simple, dramatic interaction seems to exist between an infectious agent and environmental conditions. On the one hand, without the tubercle bacillus there can be no tuberculosis; the germ is a disease-causing, or pathogenic, agent. On the other hand, many healthy people in Europe and the United States have had arrested cases of tuberculosis without ever knowing it. The bacillus may continue to exist in an individual's body with no noticeable impairment of the lungs or occurrence of the illness. In most cases, the germ becomes harmful only when physical resistance is lowered. All the elements in the relationship between the illness and the environment seem to be easily determined. A known and observable microorganism can be isolated from the sputum of all tubercular patients. The environmental changes that foster tuberculosis, such as a deterioration in diet and working conditions, can be interpreted in terms of calories, minerals, vitamins, and even working hours. Normally the disease can be arrested by sufficient quantities of nourishing foods, by rest, and by the administration of drugs.

In contrast with tuberculosis, however, the specific causes of many chronic and degenerative diseases are very obscure. Illness may occur under "favorable" as well as "unfavorable" environmental conditions. Heart disease, cancer, arthritis, and diabetes - the most important degenerative diseases of our time - claim their victims from the well-to-do and poor alike. The environmental conditions that encourage infectious disorders, such as poverty and arduous work, are often absent from the lives of persons afflicted with a degenerative disease. The course taken by a degenerative illness is highly complex, varying markedly from individual to individual. The relationship between environmental change and degenerative disorders lacks the simplicity and drama encountered in cases of tuberculosis. Hence, any emphasis on environmental change in the study of heart disease, cancer, and similar illnesses still meets with a certain amount of reserve and distrust. Everything seems to be ambiguous - the environment, its relationship to the disease, and, at times, even the disease itself.

But the picture is not so bleak as it seems. An illness is obviously environmentally induced when it becomes widespread following a major environmental change. Sharp differences of opinion are likely to arise when the change conflicts with an entrenched point of view in a particular medical specialty. A specialist in tuberculosis, for example, will regard an environmental change as harmful when it results in a reduced consumption of food and in increased physical activity. Many specialists in heart disorders, however, will regard the same change as beneficial. The traditional image of a healthy man - a plump and relatively inactive individual with a hearty appetite - was created in the last century, when tuberculosis was by far the major disease. The new, emerging image of a healthy individual is represented by a lean man who eats sparingly and who engages in a great deal of physical activity. At first glance, we seem to encounter a sharp conflict of views over the factors that promote or inhibit environmentally induced illnesses. But on closer inspection it becomes evident that both views have a common point of departure, namely, in immoderate prescriptions for diet, work, and play. From the extremes of malnutrition and arduous labor, the environmental pendulum in the Western world has begun to swing to the extremes of over nourishment and physical inactivity.



Let us examine some of the dietary extremes. At the turn of the century, many Americans ate too little to meet their physical needs. Today, they eat too much. Although the average caloric intake may be falling, the decline in the need for food is moving at a faster rate than the decline in the intake of food. A farm laborer requires about four thousand calories a day to maintain good health. Engaged in light office work, the same man would seldom require more than two thousand calories daily. Yet it is doubtful whether most Americans engaged in sedentary work limit themselves to so modest an intake of food. They tend to overeat in relation to the work they do. In fact, the average American male over thirty years of age weighs about ten to fifteen pounds more than he should.

Not only does he overeat, but he eats too much of the wrong foods. The annual per capita consumption of sugar, for example, has increased enormously in the past fifty years. "Including sugar consumed in candies, syrups jams, and jellies, as well as for table use and in cooking," observes L. Jean Bogert, "sugar consumption in the United States amounts to over 100 pounds per person yearly, or about a half pound each day for every person in the country. Our annual candy bill is over a billion dollars and has increased over 1,000 per cent in the last 60 years." There has been no noteworthy decline in the overall intake of fats. Although the consumption of butter has fallen off, the per capita intake of margarine and hydrogenated oils has increased.

Has this new form of an old environmental excess played any role in creating the modern disease landscape? The answer is almost assuredly yes. Obesity is closely linked with diabetes. Although a predisposition to diabetes is hereditary, the disease occurs primarily in overweight individuals. Proper management of the disorder involves weight regulation as well as dietary control and the use of insulin. Surprisingly, there also seems to be strong statistical evidence that obese individuals are more disposed to cancer than those who maintain their proper weight. The evidence has been summarized in a popular work on nutrition by Norman Jolliffe, of the New York City Department of Health. "Life insurance figures show that of all men who bought their policies at age 45 or over, a 25 per cent higher death rate from cancer is noted in that portion of the group which is 15 per cent or more overweight. Overweight women have a 30 to 45 per cent greater chance of developing a cancer of the uterus than those who are not fat. There is also evidence from the experimental laboratory that normal weight mice are less susceptible to both spontaneous and induced tumor formations than fat ones."

A strong suspicion exists that diets high in dairy fats, animal fats, and hydrogenated oils are implicated in the rising incidence of coronary heart disease. During World War II, the reduction in the amount of fatty goods in the diets of the people in German-occupied countries was followed by a sharp decline in the number of deaths from coronary heart illness. When the occupation came to an end and animal fats returned to the diet, the coronary death rate rose dramatically. The data collected from occupied Europe led to studies of the eating habits of Bantu and whites in South Africa, native and Hawaiian Japanese, Trappist and Benedictine monks, and many other related communities where the effects of low- and high fat diets could be compared in a meaningful way. The Bantu, the native Japanese, and the Trappists, who consume very small quantities of meat and dairy foods, are not seriously burdened by coronary heart illness. Their counterparts, whose diets are rich in fatty foods, have a high incidence of the disease. It has been established by many researchers that the consumption of animal fats raises the level of cholesterol in the blood. The greater the amount of cholesterol deposited in the coronary arteries, the greater the chances of a coronary heart attack. It should be emphasized that the level of cholesterol in the blood can be raised by non-dietary as well as dietary factors and that high cholesterol levels do not neces-

sarily result in vascular disorders. Nevertheless, there is strong statistical support for the belief that the high levels of cholesterol in the blood produced by a normally fatty diet contribute to the rising incidence of coronary heart illness.

These illustrations, needless to say, do not argue for the German occupation of Europe, the Bantu diet, or the virtues of monastic life among the Trappists. The Bantu diet is seriously deficient in nutrients vital to the maintenance of good health, and Trappist monks in contrast with the Benedictines, engage in a great deal of physical work. Many questions could be raised about non-dietary factors that may tip the scales for or against a high incidence of coronary heart illness. What role do certain undesirable habits, such as cigarette smoking, play in the occurrence of the disease? Is coronary heart illness promoted by physical inactivity and obesity, as some authorities have suggested? Indeed, does any single environmental factor determine the incidence of vascular and heart disorders in a given community? Whatever may prove to be the relationship between these diseases and diet, other factors are suspected of contributing to their occurrence, notably stress, sedentary forms of work, smoking, and a poor genetic endowment.

The problems of research would be simplified immeasurably if every environmental factor that plays a role in degenerative illnesses could be isolated and its effects subjected to precise analysis. Such clear-cut results are likely to be the exception rather than the rule. More than may be suggested by comparative studies of diet, the importance of any factor in chronic and degenerative diseases varies from individual to individual, from region to region, and from illness to illness. In the case of cigarette smoking, for example, the amount of nicotine, tars, and other harmful substances taken in varies with the brand of cigarette, the quantity of cigarettes consumed, and the amount of each cigarette that is smoked. Some individuals may have a stronger reaction to a given intake of nicotine than others. Those who exhibit no apparent ill effects from the long-term intake of nicotine may respond very gravely to tobacco tars. Finally, in many individuals smoking may tip the scales in favor of degenerative diseases that are basically caused by a harmful diet, air pollution, and stress. The analyst is confronted with a constellation of factors in which each factor is meaningful only in relation to all the others.

And here a typical disagreement arises. In the absence of conclusive evidence that a single factor contributes to all cases of an illness, many researchers are inclined to distrust the constellation as a whole. Complexity is regarded as "ambiguity," and the relationship between environment and degenerative illnesses is dismissed as "vague." This kind of thinking is characteristic of our modern *Weltgeist*. "We prefer to study systems that can easily be isolated and approached by simple methods," observed Alexis Carrel more than twenty years ago. "We generally neglect the more complex. Our mind has a partiality for precise and definitive solutions and for the resulting intellectual security. We have an almost irresistible tendency to select the subjects of our investigations for their technical facility and clearness rather than for their importance. Thus, modern physiologists principally concern themselves with physico-chemical phenomena taking place in living animals, and pay less attention to physiological and functional processes. The same thing happens with physicians when they specialize in subjects whose techniques are easy and already known rather than in degenerative diseases, neuroses, and psychoses, whose study would require the use of imagination and the creation of new methods."

This comment is still valid today, especially as it applies to attitudes toward complex, environmentally induced illnesses. The study of chronic and degenerative disorders still calls for imaginative departures from conventional approaches to disease. Tuberculosis can be explained by a germ and a number of clear-cut environmental factors. No such explanation can be found

for many chronic and degenerative illnesses. Where a contributory factor, such as tobacco tars or a high intake of fatty foods, is evident in the occurrence of a disease, it may prove to be just one of many causes. Moreover, whereas a germ has its own fixed natural history, the factors that promote degenerative illnesses often originate in man's rapidly changing synthetic environment. The influence of environmental factors, in turn, can be seen only through the human organism, whose individual differences often make it difficult to achieve clear-cut analyses.

But as research progresses, the role of environmental change in forming the modern disease landscape emerges more clearly. Many physicians are now convinced that cigarette smoking, obesity, stress, and a fatty diet have contributed significantly to the high incidence of atherosclerosis and cancer. The link between environment and illness is becoming difficult to ignore. This is not to say that every degenerative disease is environmentally induced. But it is becoming evident that all the revolutionary changes in our synthetic environment, from the rise of an urban society to the use of nuclear energy, have profound biological implications, and that these changes have added an environmental dimension to nearly every area of public health.

## **The Human Body and Illness**

The effect of our synthetic environment on health is difficult to gauge for still another reason; namely, the rigid, rather schematic approach to illness that generally prevails today. What, it may be asked, is disease? Or to put the question another way: At what point does a healthy individual become ill? These questions are not easy to answer. But the difficulties involved deserve careful examination, for they are closely related to the problems created by environmentally induced disease.

Many physicians tend to approach the human organism with a fixed threshold of illness in mind. On one side of the threshold, the body is conceived as being in good health; on the other side, it is diseased and requires treatment. The line between health and disease is generally drawn as sharply as possible. The body ordinarily must reach a certain degree of disequilibrium and damage before it is regarded as ill. This approach would be excusable if it could be attributed merely to a fragmentary knowledge of the complex processes that take place in the human body. But the approach is due, in no small measure, to a lack of interest in the "healthy" side of the threshold, where the conditions for illness are slowly created by insidious changes in the organism. Ignorance is perpetuated by a complacent indifference to many of the basic problems involved in the transition from health to disease.

The validity of this schematic approach has been challenged repeatedly by the findings of modern research in biochemistry, particularly by the results obtained from studies of human cells. It should be a truism that the majority of human illnesses are fought out on the cellular, even the molecular, level of life. Whether we survive an illness or not depends on the number and types of cells that are damaged during the course of the disease. Ordinarily, however, we tend to regard the damaged tissues of the body as the passive victims of physical disorders. When infections occur, we think of white blood cells rushing to devour bacteria and of antibodies inhibiting the effects of toxins. We seem to believe that resistance to disease is exclusively the function of certain specialized organs and systems within the body. The health and resistance of cells that are involved in the more routine functions of an organism are seldom regarded as important in the prevention or outcome of an illness.

Yet many human disorders would be difficult to explain without acknowledging the significance of general cellular well-being. An example is supplied by pellagra. Pellagra is caused by a deficiency of niacin, a member of the vitamin-B complex. A lack of niacin or of the amino acid tryptophan (a chemical precursor of niacin) produces a broad spectrum of disorders, ranging from skin eruptions to mental aberrations. As the disease progresses, changes occur in the tissues of the mouth followed by ulcerations, a slough of dead cells, and the proliferation of disease-causing germs. At this stage, secondary infections, such as trench mouth, often set in. The infections are caused primarily, not by the germs, many of which are present in healthy individuals, but rather by molecular changes within the cells which slowly lower the defenses of tissues in the mouth. The cells that line the mouth and tongue are in ill health. To borrow the words of a great American nutritionist, they have suffered a loss of "tissue integrity." The decline in cellular health, often very protracted and insidious, may not be clinically perceptible for a long time.

The concept that cells can be in ill health long before the appearance of symptoms in the form of a conventional disease, receives strong support from cancer. (Cancer cells can be regarded as ill not only because they are abnormal and produce disorders in the organism as a whole, but also because their biochemical processes seem to be impaired. For example, Otto Warburg, of the Max Planck Institute for Cell Physiology in Berlin, has advanced the theory that cancer is due to changes in the manner in which cells obtain energy. According to Warburg, cancer-causing substances damage the cell's respiratory mechanisms, causing it to obtain energy by fermentation. In cases in which cancer is caused by viruses, the cells can be regarded as infected; their reproductive apparatus is controlled or deranged by the presence of an alien agent.) Many functional differences distinguish cancerous from non-cancerous cells. Cancer cells not only multiply uncontrollably at a given site; in many cases they also spread, or metastasize, to vital organs elsewhere in the body. Metastasis accounts for most of the lives claimed by the disease. Normal cells multiply in a regulated manner and, except for certain highly specialized cells, never migrate from the tissues in which they originate. Careful studies of the development of cancer in experimental animals suggest that cells seldom become malignant until they have passed through many gradations of ill health. Any meaningful discussion of the disease must take account of healthy cells, cells in varying degrees of ill health, precancerous cells, which impart abnormal characteristics to tissues, and finally true cancer cells, which reproduce uncontrollably. Few if any of these gradations are likely to manifest themselves in noticeable symptoms of disease. Although the transition from normal to precancerous and cancerous cells may occur very rapidly, it is highly probable that the majority of malignant tumors arise only after a cell and its descendants have silently traveled a long road from health to a precancerous and then a cancerous state.

That this kind of deterioration can occur should not surprise us. Cellular metabolism is so complex that many things can go wrong in a cell without producing major symptoms of disease in the organism as a whole. A living cell engages in an enormous variety of chemical operations in which extremely complex molecules are built up and broken down at a rapid pace. A delicate balance exists between the absorption of nutrients and the excretion of waste products. If this balance is altered a trifle for any length of time, dysfunctions will occur in the cell. If it is altered a bit more, vague symptoms of illness may appear. If blood or oxygen is denied to certain organs of the body for a very short period of time, irreparable, even fatal, damage will occur.

But many disorders may persist without ever assuming an overt form. The activities of cells, tissues, and organs may be retarded; adverse changes may occur in the body's complex metabolic functions; in time, physical activity may be impaired and longevity reduced. If changes of this

nature occur in a large number of individuals, our standards of public health may be lowered imperceptibly. Such individuals will not be regarded as ill in the conventional sense of the term. In fact, until they are afflicted with cancer or heart attacks, they will satisfy all the schematic criteria for glowing health.

Fortunately, the need to give greater attention to covert, or subclinical, disturbances in the human body is gaining increasing recognition. For example, it is worth noting the way in which former U. S. Surgeon General Leroy E. Burney discusses the hazards that are created by low-level concentrations of chemical toxicants in water. "They are not killing us or making us clinically ill. But how does the human body react to steady doses of diluted chemicals? What happens if the concentration increases, either suddenly or gradually? We cannot say that we know the answers." The same problem is raised by Robert A. Kehoe, of the University of Cincinnati. After a review of the toxicants, physical hazards, radioactive pollutants, and "welter of activities" created by our synthetic environment, Kehoe asks: "But what are the consequences, through the working life time, of the frequent, almost daily, impacts of individual and collective insults of minor or sub-clinical severity?" Attention should be focused on Burney and Kehoe's concern for sub clinical damage, a concept that is not particularly congenial to the outlook of the American medical community.

It is difficult to see how the problem of sub clinical damage can be ignored in investigations of cancer and nutritional disorders. Researchers are constantly seeking better methods for the early diagnosis of malignant and pre-malignant tumors. But diagnostic techniques, however desirable, are not at issue here. If it can be inferred from the complexity of man's metabolism that ill health can exist long before it becomes medically evident, it follows that the greatest care should be exercised in changing man's environment. Where changes are desirable, they should be preceded by meticulous and imaginative studies. And where changes are necessary, every precaution should be taken to minimize any ill effects they may have on the human body. It would be utter folly to introduce needless changes in man's diet, forms of work, habits, and physical surroundings without investigating their effects from the broadest perspective of public health.

Environmental changes should be studied not only in relation to the more dramatic effects they have on man; study should also be focused on the subtle changes produced in tissues and bodily functions. In addition research should be directed toward disorders that may arise years after a new product is offered for public consumption. Whenever an inessential product is suspected of being harmful to man, its sale or distribution should be prohibited. The concept of environmentally induced illness should include all structural levels of the human organism and encompass not only present but also future generations.

## **Man and the Natural World**

Unfortunately, the amount of research devoted to environmental health falls far short of current needs. Many important problems are being neglected for want of funds and trained personnel. Where research is intensive, it is often fragmentary and uncoordinated. "Separate approaches to specific problems have had great practical value," notes a recent report by the Surgeon General to the House Appropriations Committee. "They have provided effective mechanisms for getting at critical phases of important problems... But the many and complex interrelationships among those problems have become increasingly apparent, and it is obvious that they must be considered

as parts of a whole... To achieve a 'total view,' there must be an integration of research and control methods. The knowledge and skills of many professional specialties - physicians, engineers, physicists, chemists, educators, statisticians among them - must be further coordinated in seeking scientifically sound answers to the many challenging questions in the field of environmental health."

These words are more a complaint against the absence of a "total view" than a tribute to "separate approaches to specific problems." Time is running out. Many passages in the Surgeon General's report would be dismissed as doleful exaggerations if we were not aware of the fact that they come from an official and highly responsible source. "New chemicals, many of them with toxic properties or capabilities, are being produced and marketed, and put into use at a rapid rate," the report observes. "These include plastics, plasticizers, additives to fuels and foods, pesticides, detergents, abrasives." An estimated "400-500 totally new chemicals are put into use each year... Although many commonly used chemicals are checked for toxicity, much is still unknown about their long-term potential hazards." The report warns that while "the modern supermarket and frozen food locker permit the use of a wide variety of foods, with resulting nutritional benefits,... modern methods of growing and processing foods introduce new hazards of pesticide spray residues, preservatives and other food additives, and even contaminants related to packaging, which require attention for control." An ominous generalization at the beginning of the report could well serve for its conclusion: "It is not being over dramatic to suggest that threats from our environment, actual and potential, can not only generate wholly undesirable effects on the health and well-being of isolated individuals, but under certain circumstances could affect large segments of our population and conceivably threaten the very existence of our Nation."

Despite the frankness of the Surgeon General's report, the federal government not only has failed to meet these problems resolutely but has directly and indirectly contributed to them. The indirect contribution was made through inaction. It took nearly a half century of debate, both in and out of Congress, to obtain national legislation which made manufacturers legally responsible for pre-testing food additives. Until 1959 the job of establishing whether a food additive was harmful was performed by the Food and Drug Administration, and attempts to prohibit the use of such additives often involved long and costly judicial proceedings. The same legislative procrastination is now being encountered in connection with new environmental health problems. Although air and water pollution has reached staggering proportions, national legislation to combat it is creeping forward at a snail's pace. At the same time, government-subsidized nuclear energy programs are creating one of the most hazardous sources of air and water pollution in man's environment. The harmful consequences of these programs outweigh any improvements that may have resulted from recent laws to control food additives. On balance, the over-all situation is deteriorating with every passing year.

The problems of our synthetic environment can be summed up by saying that nonhuman interests are superseding many of our responsibilities to human biological welfare. To a large extent, man is no longer working for himself. Many fields of knowledge and many practical endeavors that were once oriented toward the satisfaction of basic human wants have become ends in themselves, and to an ever-greater degree these new ends are conflicting with the requirements for human health. The needs of industrial plants are being placed before man's need for clean air; the disposal of industrial wastes has gained priority over the community's need for clean water. The most pernicious laws of the market place are given precedence over the most compelling laws of biology.

Understandably, a large number of people have reacted to the nonhuman character of our synthetic environment by venerating nature as the only source of health and well-being. The natural state, almost without reservation, is regarded as preferable to the works of modern man and the environment he has created for himself. The term "natural" tends to become synonymous with "primitive." The more man's situation approximates that of his primitive forebears, it is thought, the more he will be nourished by certain quasi-mystical wellsprings of health and virtue. In view of the mounting problems created by our synthetic environment, this renunciation of science and technology - indeed, of civilization - would be almost tempting if it were not manifestly impractical. An unqualified idealization of the natural world involves an acceptance of many environmental conditions that are distinctly unfavorable to human life. Until the advent of civilization, nature shaped the course of human evolution with severity, visiting death on all individuals who could not satisfy her rigorous requirements for survival. Millions of people are living today who could not have met the demands of a more primitive way of life. They would have perished on the battlegrounds of natural selection as surely as the young and fit are now destroyed on the battlegrounds of modern war.

A much greater impediment to a rational outlook, however, springs from a tendency to ignore man's dependence on the natural world. The extent of this dependence cannot be emphasized too strongly. The great diversity of racial types reminds us that human communities have followed their own distinctive lines of evolution. Each has adapted itself over many millennia to different climatic and physical conditions. Many subtle differences in needs exist among human groups, indeed among individual types. "Changing conditions of life affect individuals and groups," observed Wade H. Brown, of the Rockefeller Institute, a generation ago, "but as individuals differ in respect of their inherent constitutional equipment, they differ also in their reactions to influences of all kinds. Some are capable of immediate and complete adjustment, others are slow to respond or are incapable of adjustment, so that when members of a group are subjected to a change in the conditions of life or are exposed to infection under favorable or unfavorable conditions, the response obtained varies according to the capacities of the individual." Medicine and technology are providing only partial compensation for the harmful effects of new diets, changed modes of work, and unfamiliar climates. Technicians can supply a fair-skinned man with air conditioning in hot tropical regions. They can clothe a Negro in effective heat-retaining garments in the cold northlands. But these measures are only ad hoc solutions to the threat of extinction. In their new environment, both men must function as limited individuals, restricting their activities and normal mode of life.

At the same time, we should not lose sight of the needs all men have in common. Every human being has minimum requirements for certain nutrients. Although human diets may be modified by differences in climate work, and available foods, these modifications usually represent differences in nutritional emphasis, whether on proteins, carbohydrates, or fats. The human body must be employed in a variety of physical activities, or it will weaken and health and possibly longevity will be adversely affected. New toxicants dangerous to men of one race are equally hazardous to men of other races. The appearance of these toxic agents in the atmosphere, water, and foods threatens the health of every human being. As we shall see later, the extent to which they threaten man may differ appreciably from the extent to which they threaten other species, so that experimental work with animals does not always disclose the damage the new toxicants produce in human beings. For the present, it should be emphasized that the limits of environmental change were staked out by forces well beyond human control. After eons of bio-

logical evolution, man is subject to unrelenting anatomical and physiological demands. If these demands are ignored, he faces the revenge of his own body in the form of early debilitation and a shortened life span. His basic needs for optimal health have largely been decided for him by his long development as a unique animal organism. Lastly, man must live in harmony with myriad forms of plants and animals, many of which are indispensable to his survival. In the long run, a fertile soil is just as important for human health as clean air and water. Adequately nourished animals are as necessary for man's well-being as adequately nourished human tissues. Any serious disorders in the land or in plants and animals eventually produce disorders in the human body. Man tends to weaken and give way to illness as the natural preconditions for his health are undermined by erosion, disease, or pollution. Nearly all the abuses he inflicts on soil, plants, and animals are returned to him in kind, perhaps indirectly, but all the more malignantly because the damage is often far advanced before it can be seen and corrected.

We tend to view problems in the world of living things - the biosphere - with the same schematic approach that we bring to environmental health problems. We demand evidence of a marked injury to man's natural surroundings before we are ready to agree that there exist problems that require solutions. We make sharp distinctions between order and disorder in nature, just as we draw a sharp line between health and disease in man. Nevertheless, the same kinds of qualitative problems we encounter in the physiology of human beings reappear in ecology; that is, in the study of how living things interact with one another and with their environment. Every organism has its own environmentally induced illnesses. The environmentally induced diseases of plants and animals, like the chronic and degenerative diseases of man, are due to a multiplicity of factors. And just as many disorders may persist in man without ever assuming an overt form, covert illness may persist in plants and animals without ever producing clear-cut symptoms of disease.

The caution that should be exercised in changing our synthetic environment should also be exercised in changing the biosphere. Never before in man's history has there been a greater need for what Ralph and Mildred Buchsbaum call the "ecological viewpoint" toward man's influence on the natural world. This viewpoint is "the conservative view of man's relation to his total environment. It holds that an environmental setting developed by natural selection over many millions of years must be considered to have some merit. Anything so complicated as a planet inhabited by more than a million and a half species of plants and animals, all of them living together in a more or less balanced equilibrium in which they continually use and reuse the same molecules of the soil and air, cannot be improved by aimless and uninformed tinkering. All changes in a complex mechanism involve some risk and should be undertaken only after careful study of all the facts available. Changes should be made on a small scale first so as to provide a test before they are widely applied. When information is incomplete, changes should stay close to the natural processes which have in their favor the indisputable evidence of having supported life for a very long time."



# Chapter TWO: AGRICULTURE AND HEALTH

## Soil and Agriculture

Problems of soil and agriculture seldom arouse the interest of urban dwellers. Town and country have become so sharply polarized that the city man and the farmer live in widely separated, contrasting, and often socially antagonistic worlds. The average resident of an American metropolis knows as little about the problems of growing food as the average farmer knows about the problems of mass transportation. The city man, to be sure, does not need to be reminded that good soil is important for successful farming. He recognizes the necessity for conservation and careful management of the land. But his knowledge of food cultivation - its techniques, problems, and prospects - is limited. He leaves the land in trust to the farmer in the belief that modern agricultural methods cannot fail to produce attractive and nourishing food.

In reality, however, modern agronomy is beset with highly controversial problems, many of which deeply concern the welfare of urban man. It has been vehemently argued and as vigorously denied that soil fertility has a profound influence on the quality of food. According to some agronomists, deterioration in the fertility and structure of the soil results in nutritionally inferior crops. Such crops may satisfy the demands of hunger but not necessarily the requirements of human physiology. If a shift from high to low quality crops occurs on a large enough scale, man's health will be adversely affected.

Opponents of this viewpoint contend that soil fertility influences only the size of the crop and that the nutritional quality of a plant is determined primarily by genetic factors, notably the variety of seed that the farmer selects for his crop. If urban man is to exercise any control over the factors that influence his health, it is important that he gain some degree of familiarity with these problems. He need not get involved in technicalities, but he must acquire a general knowledge of soil needs and the relationship between soil fertility and the nutritional quality of crops.

Despite the sentiment and fervor ordinarily evoked by the words "land" and "soil," many people think of soil either as "dirt," a term that is often used synonymously with "filth," or as an inorganic resource, such as copper and iron. These misconceptions have not been completely eliminated by science. The rudiments of a science of soil were established in 1840, when Justus von Liebig published his monumental studies of soil and plant chemistry. Liebig had a profound grasp of his subject. He swept away many alchemistic notions about plant growth and replaced the more doubtful agricultural precepts of his day with new ones based on careful reasoning and scientific research. But Liebig also gave support to a misconception about soil that has yet to be completely removed from the public mind. He fostered the belief that soils are "lifeless storage bins filled with pulverized rocks, which held water and nutrients and which farmers stirred in tillage."

Agronomists generally agree that Liebig's conception of soil is incorrect. Although some soil scientists still hope to manipulate the soil as though it were little more than a reservoir of inorganic nutrients, few, if any, accept Liebig's approach. The soil is a palpitating sheet of life, varying

in composition not only from one part of a country to another but from acre to acre. Man can analyze the soil but he cannot manufacture it. The first difficulty he encounters is its highly dynamic character and its remarkable complexity. The soil is a highly differentiated world of living and inanimate things, of vegetable and animal matter in various stages of decomposition, and of rock particles, minerals, water, and air. Soil is always in the process of formation. It gives up its nutrients to the wind, rain, and plants, and is replenished by the breakdown of rocks, the putrefaction of dead animals and plants, and the neverending activities of microscopic life. The soil is the dramatic arena where life and death complement each other, where decay nourishes regeneration.

The surface soil, where most of the dead matter in soil is concentrated, is not the end product of decay; it is an active stage in the decomposition of organic matter. The decaying process, continually renewed by the addition of dead organisms, is as necessary for the continued existence of the soil as it is for the formation of soil. Hummus, the black or brown organic portion of the soil, is a protoplasmic, jellylike substance made up of cells, leaves, and tissues that have lost their original structure. If hummus were not renewed by the remains of dead organisms, the soil as we know it would disappear. The land surface of the earth would eventually be occupied by mineral particles and rocks, and the land would be inhospitable to advanced forms of plant and animal life.

Soil is made up of not only dead matter but living organisms. The most important of these organisms are either invisible or barely visible to the naked eye. Fungi, which initiate decomposition, and bacteria, which supply plants with usable nitrogen, are as much a part of the soil as hummus and rock particles. These soil microbes supply most of the nitrogen required for plant growth. Their work is supplemented by the activities of countless insects and earthworms, which burrow elaborate galleries through the topsoil. Without the air that these galleries provide, plant nutrition would be inhibited and bacteria would be confined to the top few inches of the soil. Earthworms continually circulate soil nutrients. During a single year they may turn up as much as twenty tons of soil to the acre, burrowing to a depth of as much as six feet below the surface. As organic nutrients pass through their bodies, they leave behind casts that give the soil increased granularity and improve its ability to support plant life.

Soil would be washed or blown away if it were not held together internally. Its connective tissue, indeed its skeleton, is made up of the root systems of the plant life it supports. Roots reach out in all directions, intertwining with one another to form a living grillage beneath the surface of the land. By interlocking and binding soil granules in a network of root branches, they increase the soil's ability to withstand the impact of rain and wind. Above the surface, the forest's canopy of branches and leaves breaks rainfall into a fine spray. The erosive runoff so often encountered in open, sloping land is changed into a gentle flow that makes it possible for much of the water to be absorbed by the subsoil. The soil is spared and the water table is kept high. Finally, when plants die, their remains not only increase the fertility of the soil but also improve its structure. Lignin in roots, stalks, and trunks keeps the soil porous and friable - structural characteristics that favor the penetration of water and air.

In addition to microorganisms, soil fauna, and plants, the fourth major factor in the maintenance and formation of soils is the activity of large terrestrial animals on the surface. Under natural conditions, the land teems with wildlife, which leaves behind organic wastes rich in plant nutrients. Nature, as Sir Albert Howard has emphasized, is a mixed farmer: "Plants are always found with animals; many species of plants and animals live together." Nature seldom cultivates

a single crop to the exclusion of all others. Variety and combination, of both plants and animals, constitute the basis for natural equilibrium. Herbivorous animals supply the topsoil with fecal matter, carnivores, in turn, regulate the number of plant eaters and thereby prevent excessive grazing. Normally, predators and their prey live in equilibrium. Rarely does it happen in the natural course of events that either group attains such numbers as to become pests and injure the soil.

Every plot of land should be viewed as a small, highly individuated cosmos. Merely identifying the organisms that promote the welfare of the soil does not adequately describe the dependence of each group on all the others. The performance of bacteria, it has been noted, depends in part on the capillarylike channels opened up by the passage of insects and earthworms through the soil. Insects and earthworms, in turn, depend for nutrients on the organic wastes of plants and animals. If the soil is structurally and nutritionally conducive to a balanced, thriving soil fauna, bacteria tend to penetrate further; top soil becomes deeper and richer; plant growth becomes healthier and more luxuriant. When plants are abundant, wildlife is better nourished and more plentiful. If any external element disrupts this cosmos, the soil deteriorates and the living things that occupy the surface are adversely affected.

As long as man is a food gatherer or a hunter, he exercises a minor influence on the soil. He acquires what he needs where he finds it, and generally he has little effect upon the natural world. When he begins to cultivate the land, however, he imposes a new and often largely synthetic environment on his natural one. The soil cosmos is altered drastically. On forest lands, a large part of the indigenous tree cover is removed and the soil is exposed to the direct assaults of rain and wind. With the restriction of animal life, the return of manure to the land becomes fortuitous. Whether the soil is properly fertilized or not depends upon man's foresight, which is usually limited to serving his shortterm economic interests. Lastly, the cultivation of a single plant species on a given tract of land tends to become the prevalent practice, and the checks and balances afforded by a diversity of vegetation are removed. The success of agriculture depends upon the extent to which man preserves the soil cosmos he inherits from nature. If the elements are merely rearranged and adequate compensation is made for necessary changes, the cultivation of food can continue indefinitely without harm to the soil; in fact, virgin soil can be improved immeasurably. But if the soil cosmos is undermined, soil will begin to disappear and the land will be forced to function with, as it were, its vital organs exposed and half its viscera removed.

The results can be disastrous. History supplies us with numerous accounts of civilizations that disappeared solely because of poor agricultural practices. Throughout the Mediterranean world, vast manmade deserts have supplanted rich, fertile lands that once nourished luxuriant crops and supported large populations. In North Africa, for example, a terrible price has been paid for the ancient plantation economy, in which land was cultivated for a few cash crops. The Phoenician merchants who established Carthage found a semiarid but highly fertile soil on the southern shores of the Mediterranean Sea. Almost at the outset, farming assumed a highly commercialized form. A large acreage was irrigated and cultivated by slaves, and crops were planted and harvested primarily for the money they would bring in. "The intensive plantation cultivation which the Carthaginian plantationowner undertook, and which was subsequently imitated by the Roman conquerors of the land, had the longterm effect of letting in the desert," Edward Hyams writes. "Conceivably, the original forest - and grass - soil communities might have acted as a barrier to the advancing sand, might have even pushed slowly southward, carrying a more humid climate with them as trees invaded the grass, and colonized the Sahara. But cultivation

which took no account of soil as such, and was concerned with getting the largest possible crops out of the soil, had the opposite effect. The Sahara began its northward march; it has been on the move ever since; it has already invaded Europe, by way of Spain, an old African trick."

It is not difficult to see that the agricultural practices that reduced fertile areas of the Mediterranean world to a desert are being repeated today, especially in many areas of the United States. Both the forms and the effects are often the same. Modern agriculture tends to model itself on industry. Tens of thousands of acres are planted and harvested on a factory schedule, in some cases to meet the daily production requirements of a nearby food processing plant. Every method that will "hurry along" cultivation and reduce its cost is eagerly seized upon. Food cultivation is rigorously standardized, even "time studied." The division of labor in agriculture is developed to a point where the term "farmer" becomes a most general expression, applicable to pilots who spray insecticides from the air, truck and tractor drivers who merely operate vehicles, mechanics who repair farm implements, foremen who manage workers, and underprivileged migratory laborers, working at piece rates, who view the needs of the land with complete indifference. Husbandry is almost entirely subordinated to mass production. The modern land factory, like the metropolis that it feeds, tries to base the management of living things on a pernicious average. It employs primarily those methods that promote mass manipulation at the lowest cost.

Practices of this sort are as harmful to soil as they are to men. Modern agriculture often demands the largest possible farm machinery to handle its huge crops; heavy tractors move over the same area of land repeatedly - planting, spreading fertilizer, and harvesting crops. Although the use of machines in the performance of arduous tasks is certainly desirable from a human point of view, every mechanical advance should be properly scaled, both in size and form, to the situation at hand. The land is not the concrete floor of a factory; it is a living thing, and it can be mauled and bruised. Injury to the soil, often of a serious nature, inevitably follows the exposure of fields to the weight of extraordinarily heavy machines. The soil becomes compacted, and as a result, proper drainage and the growth of roots are inhibited. Data from Texas indicate that crop yields of compacted soils there have fallen off from 40 to 50 per cent, and commercial fertilizers have not been able to increase the yields to any great extent. "After 100 years of farmimplement development," observes Howard W. Lull, of the U. S. Forestry Service, "more than half of Germany's cultivated soils are in poor condition - due largely to compaction by tractors. In Great Britain, the rapid increase in the weight of tractors in recent years has led to predictions of serious effects on the soil."

The deterioration of soil is carried further when large areas of land are used to cultivate a single crop. The land factory separates not only animal from plant, but plant from plant. Precisely where plant and animal wastes are most needed to help the soil withstand the weight of heavy machinery, a strong emphasis is placed on monocrop agriculture and industrial methods. The structure of the soil breaks down and the layer of hummus begins to disappear. In many areas of the United States, the land has been turned into a nearly lifeless, inorganic medium that must be nursed along like an invalid at the threshold of death.

The term "inorganic medium" can be taken literally. Modern agriculture may be distinguished from earlier forms of cultivation by its reliance on chemistry for soil nutrients and the control of insect infestations. With the removal of many natural checks and balances, we are compelled to use many synthetic materials to grow and protect our foods. These chemical agents enable us to produce large crops on indifferent and even poor soils. The ultimate is reached with hydroponics, which uses no soil at all. An open box is filled with pebbles and a solution of inorganic nutrients.

Then seeds or roots are placed directly in the medium, or sometimes seeds are supported in the solution by a wire screen until they germinate and sink their roots into the pebbles. With adequate light, proper temperature, and the appropriate renewal of inorganic nutrients, the plants mature rapidly and become an edible crop.

In an age of demonstrable scientific achievement, it is hardly necessary to emphasize the agricultural importance of chemistry. Chemical analysis has advanced our knowledge of the soil cosmos and plant nutrition enormously, and there is no a priori reason why manmade chemical agents cannot be used to considerable advantage in increasing the fertility of the soil. Soil is fertilized to increase the quantity and quality of food crops. Wherever man acquires the knowledge and the chemical agents to achieve these ends, he enjoys a decisive advantage over less developed agricultural communities. Natural processes can be rendered more efficient and some of the life lines that determine the abundance and quality of plants can be shortened, both to the advantage of man and the organisms on whose wellbeing he depends. If rational standards were applied to agriculture, it would be possible for farmers to systematically meet various needs of the land that would probably have remained unsatisfied if the solution of soil problems had been left to natural processes alone.

But there is a danger that the techniques of modern chemistry will be abused. This danger is especially pronounced in an age of scientific achievement, in which a limited amount of knowledge tends to create the illusion that our command of the agricultural situation is complete and our standards of agricultural success are rational. Modern society places a strong emphasis on the merits of mass production. We tend to confuse quantity with quality. The thoughtless use of chemical agents in the production of food may well make it possible to grow crops of great abundance but of low quality on soil that is basically in poor condition. "High yields are not... synonymous with a high content of nutrient elements," observes A. G. Norman, of the University of Michigan "Crops from well fertilized plots may have a lower content of some essential elements than those from poorly yielding plots, the addition of a fertilizer may cause a reduction in content of some of the other nutrient elements, or, if the supply of the major elements is such that the content of each in the plant falls in the poverty adjustment zone [where a partial deficiency of nutrients exists], moderate addition of one of them may have rather little effect on content."

Without making a fetish of nature, a number of responsible agronomists and conservationists doubt strongly whether a basically poor soil is capable of meeting all the nutritional requirements of plants, animals, and man with the support of a few chemical fertilizers. "In the long run life cannot be supported, so far as our present knowledge goes, by artificial processes," observes Fairfield Osborn, a noted American conservationist. "The deterioration of the lifegiving elements of the earth, that is proceeding at a constantly accelerating velocity, may be checked but cannot be cured by manapplied chemistry." Osborn sees two basic reasons why "artificial processes, unless they are recognized as complements to natural processes, will fail to provide the solution" to current soil and health problems. "The first is concerned with the actual nature of productive soils," by which is meant the complexity of the soil cosmos. "The second reason is a practical one and hinges upon the difficulty, if not impossibility, of instructing great numbers of people who work on the land regarding the extremely complicated techniques that need to be applied to produce even a reasonable degree of fertility by artificial methods."

Whatever one may think of Osborn's conclusions, the issue is obviously of great importance in any discussion of environmental health, and it raises the additional question of one's approach to

our synthetic environment. Knowledge is never absolute. What we "know" about anything, be it soil or nutrition, generally consists of the facts that are selected for our purpose. If our objectives are comprehensive, so too will be the data they command. If they are limited, the data adduced in their support may entail a suppression, conscious or unconscious, of facts that support broader objectives. The physician who is burdened with a schematic conception of disease is inclined to ignore subtle functions of the body whose impairment contributes to the incidence of chronic and degenerative illnesses. Similarly, the agriculturist who is guided primarily by such quantitative criteria as the size of the crops is inclined to ignore ecological processes whose impairment may lower the nutritional quality of food. The evidence that both adduce in support of their views, such as man's greater longevity and larger crops, does not prove that man's longer life span is the result of better health or that the abundant crop is greater in food value.

The tendency to place the soil on a limited ration of chemical fertilizers becomes stronger with each passing year. Nearly a decade ago, George L. McNew, of the Boyce Thompson Institute for Plant Research, observed that the quantity of inorganic fertilizers used in agriculture had increased over 200 per cent between the prewar years and 1948. "Less barnyard manure is being added to the soil each year. Not enough green manure from cover crops is being plowed under to maintain the organic matter content in soils on most of our farms." The implications of this change in agricultural methods call for sober consideration. We must closely examine the way in which current fertilization practices are likely to affect the nutritional quality of food, especially in circumstances where economic incentives are likely to make misuses of chemicals the rule rather than the exception.

## Soil Fertility and Nutrition

Before we can understand the role that soil fertility plays in environmental health, an important question must be answered. Do we have a complete knowledge of the nutritive constituents of common foods and do we fully understand the function that all the known nutrients have in the human body? Many researchers in the field of nutrition and in related sciences agree that the answer is no. "There is no known laboratory method or group of methods by which all the nutritive constituents in a food can be measured and evaluated in terms of the nutrition of man or animals," observes Kenneth C. Beeson, formerly director of the Department of Agriculture's Plant, Soil, and Nutrition Laboratory. "... All of the constituents contributing to nutritive quality have probably not been recognized and there are no adequate methods for quantitative measure in many constituents that we do recognize."

The same problem is stated very clearly by Bruce Bliven in a popular discussion of hydroponics. "We do not know whether we have yet enumerated the entire list of chemicals and other substances necessary for the maintenance of health and vigor. The 'trace minerals' that occur in minute quantities in our food, including cobalt, copper, phosphorus, manganese, iodine, and others, are known to be of enormous importance to health, though we are not yet sure just how many of them are required, or in what quantities. We do not even know how many vitamins there are, or which are essential. Theoretically, it should be possible to produce fruits and vegetables from soil that is lacking in some of the substances necessary for the health of animals and man; these fruits and vegetables would look all right, and yet prove to be harmful if they were a principal part of the diet."

The possibility of producing plants that 'look all right' but vary widely in nutritional values is more than theoretical; such cultivation is eminently practical and very common. Identical varieties of vegetables, fruit, and grain may differ appreciably in mineral, protein, and vitamin content. These variations are caused by many factors, a number of which are not within man's control. For example, the vitamin C content of fruit and leafy vegetables seems to depend primarily upon the amount of sunshine to which the plants are exposed. Variations in temperature influence the production of thiamine and carotene in different plant species. The longer the growing season, the greater will be the amount of vitamin C in beans, spinach, and lettuce. Aside from these climatic and seasonal factors, however, a decisive role in plant nutrition is played by soil fertility. Despite sharp differences of opinion that have developed around the issue of soil and nutrition, a large amount of evidence supports the conclusion that the nutritional quality of plants is influenced profoundly by the fertility of the soil.

This influence may be beneficial or undesirable, depending upon the type and quantity of fertilizer used in any given agricultural situation. In general, nitrogen fertilizer tends to increase the proportion of crude protein in grain. This relationship has been established in several experiments. During the late 1940's, research by R. L. Lovern and M. F. Miller at the University of Missouri showed that the percentage of crude protein in one variety of wheat could be raised from a minimum of 8.9 to a maximum of 17 by successive applications of soluble nitrogen to the soil. Three years of experimental work by A. S. Hunter and his coworkers on 133 farms in the Columbia Basin counties of Oregon indicated that applications of nitrogen fertilizer usually increase the amount of protein in pastrytype wheats. Results of a similar nature have also been achieved with corn. H. E. Sauberlich and his colleagues at the Alabama Agricultural Experiment Station cultivated two grades of corn - a 'low protein' grain (6.8 to 9.1 per cent) and a 'high protein' grain (9.5 to 13.6 per cent). The 'high protein' corn was produced by increasing the application of nitrogen fertilizer to the soil.

When agronomists turn their attention from the protein to the mineral constituents of plants, they find that soil fertility exercises a more subtle influence on nutritive quality. The addition of calcium, phosphorus, potassium, and other nutrients to depleted soils often increases the mineral content of plants; but the experiments do not yield consistent results. In many cases an increase does not take place. In fact, if the soil is not deficient in common minerals, attempts to increase yields by adding high concentrations of commercial fertilizers to the soil may actually reduce the nutritive quality of plants. The soil may become "overfertilized," and the quantity of important nutrients in the crop will diminish.

How are these contradictory results to be explained? A partial answer is provided by the findings of soil chemistry and plant physiology. Many factors may inhibit a plant's uptake and utilization of a nutrient. Research workers have discovered that an excessive quantity of one nutrient in the soil may prevent the absorption and utilization of another. "Too much nitrogen, for example, in proportion to the phosphorus available to plants, may encourage undesirable physiological conditions. Also too much calcium may interfere with phosphorus and boron nutrition or may encourage chlorosis [lack of chlorophyll] due to a reduction in the availability of the soil iron, zinc, or manganese." Several key nutrients have been paired together on the basis of such interactions, notably calcium and magnesium, iron and manganese, and cobalt and manganese. Moreover, it would be incorrect to assume that a simple one-to-one relationship exists between available soil nitrogen and the protein content of plants. Proteins differ markedly in nutritional value. By applying excessive quantities of commercial nitrogen fertilizer to the soil, a farmer

may well produce a lush crop that contains less highquality and more lowquality proteins than crops cultivated on properly fertilized soils. An objective review of the evidence at hand not only justifies the conclusion that soil fertility influences the nutritive quality of food; it also leads us to believe that this influence is more complex and more subtle than was formerly suspected. A balanced array of nutrients, modified where necessary to satisfy the needs of a specific soil, is indispensable to the cultivation of highly nutritious crops.

At a time when many farmers are trying to cultivate large crops by supplying the soil with a few highly concentrated inorganic fertilizers, it would be appropriate to emphasize the important role that organic matter plays in plant nutrition as well as in the reconstruction of soil. Organic matter is extremely complex and highly varied in nutritional content. Manure, for example, will not only supply soil with adequate quantities of nitrogen released by microbes in close accord with the plant's needs; it will also add most of the nutrients that plants require for growth and wellbeing. No one seriously claims that manure alone meets all the needs of a crop, but its array of nutrients is probably unequaled by the commercial fertilizer preparations that are normally used today.

The use of organic fertilizers has often made the difference between successful food cultivation and outright crop failures. Until well into the 1920's, many American agronomists were convinced that soil merely required heavy dosages of nitrogen, phosphorus, and potassium - the wellknown NPK formula - to produce flourishing crops. These elements, it was supposed, were all that organic fertilizers contributed to plant nutrition. When inexpensive commercially prepared fertilizers became available, nitrogen, phosphorus, and potassium compounds replaced manures, bone meal, and plant residues. Serious crop failures often followed the changeover. In Florida, for example, nutritional deficiencies appeared in citrus and tuna trees; they were corrected by a return to the use of organic matter. Intensive research disclosed that bone meal supplied citrus trees with sorely needed magnesium in quantities that were not provided by the inorganic compounds in use at the time. Fortunately, the deficiency appeared in an acute form; it was easily discovered and later corrected by new chemical agents. But success in correcting acute nutritional deficiencies is likely to lower our guard against insidious deficiencies that may not manifest themselves as clearcut plant disorders. Many plants may require nutrients in amounts that are not supplied by commonly used inorganic preparations.

The majority of commercial fertilizers in use today are relatively simple chemical preparations. The farmer deliberately replaces complex, bulky, slowacting organic materials with a few soluble, purified, inexpensive, and easily handled salts. The regulation of soil fertility now falls for the most part to man. "The agronomist and the farmer are ordinarily preoccupied with yield," Norman writes. "They are rarely concerned with mineral composition. The varieties selected, the cultural practices followed, the fertilizers applied, all are decided on the basis of yield expectation." The manipulation of soil fertility in accordance with this criterion may produce very curious results. For example, in studies conducted at the Missouri Agricultural Experiment Station, it was found that by changing the ratio of calcium to potassium, it was possible to increase the vegetative bulk of soybeans by one fourth. "Such increased tonnage would warrant agronomic applause," observes William A. Albrecht, of the University of Missouri. "But this increase in vegetative mass represented a reduction in the concentration of protein by one fourth, a reduction in the concentration of phosphorus by one half and a reduction in the concentration of calcium by two thirds over that in the smaller tonnage yield" produced by a different ratio of calcium to potassium.



Although heavy applications of NPK fertilizer to the soil often produce lush, abundant forage, the crop may be very deficient in key nutrients. Beeson presents a summary of an interesting experiment by H. A. Keener and E. J. Thacker at the New Hampshire Agricultural Experiment Station that clearly illustrates this point. "Excellent yields of bromeladino or timothy hay produced in New Hampshire with high level applications of fertilizer have failed to provide an adequate forage for calves. Deficiency symptoms observed in calves are poor growth, rough coats, anemia, sagging of the spinal column behind the shoulders, an ataxia [lack of coordination] of the hind legs (timothyfed calves only), loss of tips of ears, and broken bones." Supplements of copper and iron did not remove any of these symptoms. When similar hay was fed to rabbits, the same deficiency symptoms appeared.

A chemical analysis of samples from the crop would not have disclosed the complete extent of the deficiency. At first Keener and Thacker suspected that the "timothy hay was deficient in iodine and one or more organic factors," but later studies by Thacker showed that the "deficiency in the hay was related to its mineral composition." Similar experiments have led many agronomists to conclude that the nutritional value of a crop must be judged primarily by the response of the organism that consumes it, not merely by chemical analyzes of the soil and the plant.

If the adequacy of our agricultural methods is judged by the health of our livestock, then American agriculture must be regarded as a failure. The health of our domestic animals has been deteriorating noticeably for years. Veterinary medicine has been able to reduce the incidence of infectious diseases in livestock and poultry primarily because of new antibiotic preparations, but the resistance of the animals is very low. The number of cattle with cancers of the lymph and bloodforming organs that are being condemned at federally inspected packing plants has increased from 9.2 per 100,000 in 1950 to 18.2 in 1959, nearly 100 per cent in nine years; during the same period the number of swine condemned for similar cancers rose 97 per cent. Sterility in animals is arousing deep concern. "The most important problem in the beef industry is poor reproductive performance, as evidenced by low percentage calf crops," note a group of investigators at the Beltsville Experiment Station in Maryland. (The experimental work reported by these investigators shows that diet is a prime factor in the reproductive performance of animals. By increasing, decreasing, or changing the composition of the ration, the Beltsville researchers found that beef cows respond with remarkable variations in fertility, sexual activity, and the ability to deliver offspring. A moderate but balanced ration of carbohydrates and proteins yielded the highest reproductive rates.) The ubiquitous environmental changes of our time seem to have affected animal life as profoundly as they have affected man.

Every problem, to be sure, should be placed in its proper setting. The use of highly concentrated chemical fertilizers and massproduction techniques increases agricultural output at relatively small cost and with little effort. If the purpose of growing food is to prevent famine and acute nutritional disorders, these methods produce immediate results. They satisfy the dire need for food, and they remove the more obvious diseases produced by an inadequate diet. But if we enlarge our view of modern agriculture to include such problems as the quality of food and the health of plants, livestock, and human beings, the success that is ordinarily claimed for current agricultural techniques requires qualification. Man does not practice agriculture in a vacuum. His activities as a cultivator of food are influenced more by his forms of social organization than by his solicitude for the needs of the soil. The majority of American farmers, large and small, cultivate food as a business enterprise. They try to produce large crops at a minimum cost. As it may well be difficult to increase the output of the soil without lowering the quality of crops, the

farmer who places quality above quantity can scarcely hope to survive the competitive demands of American agriculture. Accordingly, we can expect any technique that promotes large crops to be carried to the point of abuse. Economic competition leaves the farmer little choice but to replace low standards of food cultivation with even lower ones.

It is highly probable that exploitation of the soil has already produced a deterioration in the nutritive quality of crops in many parts of the United States. William A. Albrecht, one of America's most perceptive and creative agronomists, suggests that more carbohydrates and fewer high-quality proteins tend to appear in our food staples with the passage of time. The extent of this shift in nutritive quality is difficult to determine. Commercial foods are generally graded according to appearance, and very little attention is given to nutritive quality. The information that is available, however, is not encouraging. Albrecht has pointed out that between 1940 and 1949 the concentration of protein in Kansasgrown corn declined from 9.5 to 8.5 per cent, although the decade was marked by substantial increases in corn yields. "It is interesting to note the reduction in the protein content of corn as reported in successive editions of a standard handbook of feeds and feeding. In the Eleventh Edition, published 40 years ago, the only figure quoted for crude protein of dent corn was 10.3 per cent. In the TwentyFirst edition, 1950, five grades of corn were cited, for which the protein figures ranged from 8.8 to 7.9, with a mean of nearly 8.4 per cent. During the interval of 40 years between the two editions, crude protein in corn dropped from 10.3 to 8.4, a reduction of 22 per cent."

There also seems to be evidence of an overall decline in the protein content of Kansasgrown wheat. "A survey of the percentage protein of Kansas wheat grain made in 1940 showed a range of 10 to almost 19 per cent," Albrecht notes. "In a similar survey ten years later, in 1949, protein concentration was found to range from 9 to less than 15 per cent."

We can ill afford such losses. At a time when many individuals are consuming substantially more food than they require for the work they do, an increase in carbohydrates at the expense of proteins is obviously undesirable, particularly for middleaged people. Great importance should be attached to the quality of the food we consume. We are continually being reminded that there is a close connection between obesity and chronic diseases. An overweight individual has a greater chance of acquiring cancer, diabetes, and cardiovascular disorders than one who maintains his proper weight. Any shift in the quality of foods that results in an increase of carbohydrates can be expected to contribute to the erosion of public health.

Viewing nutritional problems in a broader perspective, it is difficult to believe that human fitness can be maintained while the soil is gradually deteriorating. Albrecht observes: "Man has become aware of increased needs for health preservation, interpreted as a technical need for more hospitals, drugs, and doctors, when it may simply be a matter of failing to recognize the basic truth in the old adage which reminded us that 'to be well fed is to be healthy.' Unfortunately, we have not seen the changes man has wrought in his soil community in terms of food quality for health, as economics and technologies have emphasized its quantity. Man is exploiting the earth that feeds him much as a parasite multiplies until it kills its host. Slowly the reserves in the soil for the support of man's nutrition are being exhausted. All too few of us have yet seen the soil community as the foundation in terms of nutrition of the entire biotic pyramid of which, man, at the top, occupies the most hazardous place."

## Environment and Ecological Patterns

There is a close relationship between modern concepts of progress and man's attempt to control the forces of nature. From the time of the Renaissance, man has tended to evaluate nearly all the advances of society and science in terms of the amount of power over the natural world which they gave him. The word "power," however, has many shades of meaning. To the men of the Renaissance and the Enlightenment, it would have seemed preposterous that power over nature meant more than living in harmony with the natural world. Like the animals around him, man was a product of natural forces and depended upon nature for his survival and wellbeing. What made him unique in the animal kingdom was his ability to reason. This faculty gave him the power to remove fortuity from his relationship to nature, to bring a certain degree of guidance to natural processes. He could try to mitigate the harshness of the natural world and make the interplay of natural forces relatively benign. Power over nature was regarded as the ability of man to enter into conscious symbiosis with the biotic world.

With the Industrial Revolution, the concept of power over nature underwent a radical change. The word "nature" was replaced by the phrase "natural resources." The new captains of industry regarded land, forests, and wildlife as materials for wanton exploitation. The progress of man was identified with the pillage of nature. The needs of commerce and industry produced a new ideology: There are no dictates of nature that are beyond human transgression. Technology, it was claimed, is capable of giving man complete mastery over the natural world. If these notions seem naive today, it is because the needless, often senseless, conflict between man and nature is yielding unexpected consequences. We are now learning that the more man works against nature, the more deeply entangled he becomes in the very forces he seeks to master.

The problems created by our conflict with nature are dramatically exemplified by our chemical war against the insect world. During the past two decades, a large number of insecticides have been developed for general use on farms and in the home. The bestknown and most widely used preparations are the chlorinated hydrocarbons, such as DDT, methoxychlor, dieldrin, and chlordane. The chlorinated hydrocarbons are sprayed over vast acres of forest land, range land, crop land, and even semiurban land on which there are heavy infestations of insects. It is doubtful whether any part of the United States with some kind of vegetation useful to man has not been treated at least once in the past ten years. Most of our fields and orchards are sprayed recurrently during the growing season. Aside from the hazards that insecticides create for public health, many conservationists claim that extensive use of the new insecticides is impairing the ability of wildlife and beneficial insects to exercise control over pests. They point out that the insecticides are taking a heavy toll of life among fish, birds, small mammals, and useful insects. There is a great deal of evidence that the new chemicals are selfdefeating. Not only have they failed to eradicate most of the pests against which they are employed; in some cases, new pests and greater infestations have been created as a result of the damage inflicted on predators of species formerly under control.

To understand this problem clearly, it is necessary to examine the conditions that promote infestations of pests. A species becomes a pest when it invades a new area that is not inhabited by its natural enemies or when environmental changes occur that provide more favorable conditions for its growth. Under natural conditions, infestations are episodic and rare. An increase in the pest species creates propitious conditions for those predators that live on the pest. The proliferation of the pest encourages the proliferation of its predators and attracts additional enemies from nearby

regions. Whichever way the problem is solved, the remarkable diversity and adaptability of life under natural conditions seldom permit the pest to get completely out of hand.

Insect infestations become persistent and serious, however, when natural variety is diminished by man. Agriculture, especially when limited to one crop, tends to simplify a natural region. "The first person to harvest and store natural cereal grain for later sowing started the simplification of agriculture," observes Robert L. Rudd, of the University of California. "Until the mechanization and later chemicalization of agriculture, there was little substantial departure from the methods of the first agriculturalists. Acreages were small, landscapes diverse." The simplification of ecological systems "was relatively slight and was in any event local. Hedgerows, trees, weed patches, seasonal cropping and multipurpose farming combined to form a diversified base for a diversified fauna. Mechanized and chemicalized crop production has resulted in large expanses of single crop species - the destruction of diversity in the landscape."

Simplification of the landscape, followed by a diminution in the variety of fauna, creates highly favorable conditions for an infestation. A potential pest is left with a large food supply and a small number of predators. The job of eradicating the pest, like that of fertilizing the soil, falls primarily to man, and thus far the methods employed and the results achieved have been very unsatisfactory. Man can usually eradicate a pest - but only for a while. In the process, he often eradicates nearly every other form of life in the area aside from the crop. When the pest returns, as it often does, the ecological system may have been so simplified by the pesticidal treatment that the new conditions are more favorable for infestation than the old. "Initial chemical control, therefore, creates the later need for more chemicals," Rudd adds. "Once begun, there is no stopping if the crop is not to be lost."

Many responsible conservationists regard the nonselective spraying of open land and forests as an ecological "boomerang." In a number of cases, the damage inflicted on beneficial insects outweighs the damage inflicted on the pest. Pesticidal treatments have started infestations that would have been very mild, if not averted entirely, had the treatment not been used. In one region, for example, the treatment of a stand of timber with a fivepoundperacre dosage of DDT in early summer resulted in a general infestation of at least fourteen species of aphids. The aphids, clinging to the undersurface of the leaves, survived the spray, but their predators were decimated and failed to reestablish themselves rapidly enough to check the infestation. In still other cases, controlled insects have been transformed into serious pests by the destruction of their predators through spraying programs aimed at an entirely different species of pest. For example, until fairly recently the redbanded leaf roller caused very little damage in apple orchards, although widely distributed, the insect was strictly controlled by parasites and predators. "Rare indeed was the orchardist who knowingly had to contend with it," writes Howard Baker, of the Bureau of Entomology. "Now it is a problem pest throughout the Midwest and East, where in 1947 and 1948 particularly it caused severe damage in many orchards." The insect became a pest after its parasites had been destroyed by DDT. To control the leaf roller, orchardists are now compelled to supplement DDT treatments with TDE and parathion. "Never before... have so many pests with such a wide range of habits and characteristics increased to injurious levels following application of any one material as has occurred following the use of DDT in apple spray programs."

Nonselective spraying programs are taking a heavy toll of life among birds and rodents - animals that play a major role in limiting infestations of harmful insects. Although rodents are generally regarded as little more than pests themselves, forest rodents are voracious consumers of insects. On an average, insects constitute 20 per cent of the diet of forest mice, chipmunks, and

flying squirrels. The importance of birds in insect control scarcely requires emphasis. Suffice it to say that naturalists who have made careful counts of insects in the stomachs of birds have found, for example, 5,000 ants in a flicker, 500 mosquitoes in a night hawk, and 250 tent caterpillars in a yellowbilled cuckoo. A brown thrasher will eat more than 6,000 insects in a single day; a swallow, about 1,000 leaf hoppers. Spraying commonly destroys an appreciable number of these creatures, even when the program is fairly limited in scope. To cite a case in point: In 1956 the Cranbrook Institute of Science, in Michigan, undertook a limited survey of the decline in bird life produced by DDT spraying programs to control the Dutch elm disease. Residents of the immediate area were asked to turn in or report to the Institute any birds suspected of having been poisoned by DDT. "During April, May and June of that year, but mostly in May, more than 200 dead and dying birds were turned in to the Institute... By 1959 the number of specimens received had mounted to about 400, with an estimated 600 calls or reports regarding birds not turned in." A survey of the bird life on the Cranbrook campus showed that the breeding population declined from 250 pairs to 25 or less. Most of the dead and dying birds were robins that were probably poisoned by eating worms impregnated with DDT.

A more extensive survey was made during the widely publicized fireant campaign that the Department of Agriculture initiated in November 1957. The data, compiled by the National Audubon Society, deal with many animals, including more than a hundred head of cattle killed in an area near Climax, Georgia. We shall confine ourselves, however, to losses among birds. "The drastic effect of applying insecticide during the birdnesting season was dramatically shown in Texas. In a 60acre clover field bird numbers declined alarmingly: 38 of 41 nests with eggs were abandoned or destroyed. Lay's Texas report summarizes the devastating results tersely as follows: 'Bird populations along ranch roads in the treated areas were reduced 92.97 per cent in two weeks. Bird populations within acre plots studied were reduced 85 per cent in two weeks. Nesting success of birds in the area was reduced 89 per cent (compared with a nontreated area).' Lay adds, 'Large scale abandonment of nests with eggs could be explained only by the mortality of the adults. The missing birds did not appear in adjacent areas.' "

To aggravate the damage, insecticides are carried by surface and ground water into streams and lakes, where they kill large numbers of aquatic animals. For example, one pound of dieldrin per acre, applied to a large tract of land in St. Lucie County, Florida, destroyed twenty to thirty tons of fish. During 1958, a DDT campaign against the spruce budworm in northern Maine killed thousands of trout and other game fish; as long as three months after spraying, trout were found whose bodies contained DDT concentrations of from 2.9 to 198 parts per million. The sprayers were not entirely unaware of what the consequences of the program would be. Two years earlier a campaign of much the same kind produced heavy losses of young salmon in the nearby Miramichi River system of New Brunswick, Canada. "As expected, an alarmingly reduced adult Atlantic salmon run was noted in 1960 when the 1956 hatch returned to spawn in the Miramichi River system."

The discovery of DDT led to a widespread belief that insect pests could be eradicated by relying exclusively on the use of chemical agents. This belief was severely shaken when it was found that a number of harmful species were producing strains that were resistant to existing insecticides, and now many entomologists suspect that the appearance of such strains in nearly all major species of pests is merely a matter of time. As long as present methods of control are employed, new insecticides will be required every few years just to hold the line in man's chemical war against the insect world. The appearance of resistant strains among man's most formidable insect

enemies has profound biological implications. In addition to all the harm man has inflicted on the land and the biosphere, he is now becoming a selfdamaging selective force in the insect world. Insecticides do not make "the susceptible more resistant," A. W. A. Brown observes, "for they are dead. Rather, the chemical had discovered the favored few that had a certain margin of resistance and selected them to survive and breed. Normally they would be eliminated by parasites and predators, to whom this kind of resistance means nothing. But if the chemical treatment has removed the biological control species, the more resistant individuals of the pest species can survive to breed... It is ironic that the economic entomologist has thus been able to speed up evolution to man's own disadvantage."

Brown's conclusion is an indictment of our methods of dealing with the natural world. Biological evolution has been governed not only by the survival of the fittest but also by the ability of living things to assume an inexhaustible variety of forms. The world of life has met every change in climate and landscape with a more diversified and interdependent biosphere. Each stage of organic evolution has been marked by a greater degree of specialization, complexity, and inter-relatedness than the preceding one. Almost every species that has been "selected" for survival exhibits a higher order of specialization and depends for its continued existence upon a more complex environment than its predecessors.

Modern man is undoing the work of organic evolution, replacing a complex environment with a simpler one. He is disassembling the biotic pyramid that has supported human life for countless millennia. Almost all the manifold relationships on which man's food plants and domestic animals depend for health are being replaced by more elementary relationships, and the biosphere is slowly being restored to a stage in which it will be able to support only a simpler form of life. It is not within the realm of fantasy to suggest that if the breakdown of the soil cosmos continues unabated, if plant and animal health continue to deteriorate, if insect infestations multiply, and if chemical controls become increasingly lethal, many of the preconditions for advanced life will be irreparably damaged and the earth will prove to be incapable of supporting a viable, healthy human species.

The simplification of man's environment has evoked deep concern among ecologists, particularly in connection with the insect problem. Only in the "conscious pitting of one living thing against another - biological control - can we directly control pests without the hazards accompanying repetitive chemical applications," Rudd writes. "... European entomologists now speak of managing the entire plantinsect community. It is called manipulation of the biocenose. The biocenetic environment is varied, complex and dynamic. Although numbers of individuals will constantly change, no one species will normally reach pest proportions. The special conditions which allow high populations of a single species in a complex ecosystem [a pattern of life] are rare events. Management of the biocenose or ecosystem should become our goal, challenging as it is."

Needless to say, the soil is no less an ecosystem than the complexes established by plants, insects, and animals. When an agronomist emphasizes that organic matter is vital to the fertility of the soil, his emphasis derives from an appreciation of the manifold requirements of the soil cosmos and plant nutrition. Although organic matter is not a panacea for the ills of agriculture and human health, it provides good crops and it supplies plants with nutrients in a manner that has met the requirements of plant life over long ages of botanical evolution. The role played by chemical fertilizers in agriculture may be very important, especially in circumstances where animal and plant wastes are in short supply or where man's need for food is pressing. But the

value of chemical fertilizers lies in their ability to complement the nutritional diversity of organic matter, not to supplant animal and plant wastes entirely.

An ecological point of view that emphasizes the use of organic materials and the practice of biocenetic control admittedly restricts man. It requires him to reconstruct the agricultural situation along more natural lines, to defer to the dictates of ecology rather than those of economics. To borrow the words of Charles Elton, this point of view is not intended "to promote any idea of complete laissez faire in the management of the ecosystems of the world... The world's future has to be managed, but this management would not be just like a game of chess - more like steering a boat. We need to learn how to manipulate more wisely the tremendous potential forces of population growth in plants and animals, how to allow sufficient freedom for some of these forces to work among themselves, and how to grow environments... that will maintain a permanent balance in each community."

# CHAPTER THREE: URBAN LIFE AND HEALTH

## The Changing Urban Scene

Man's environment attains a high degree of simplification in the modern metropolis. At first this may seem surprising: We normally associate metropolitan life with a diversity of individual types and with variety and subtlety in human relations. But diversity among men and complexity in human relations are social and cultural phenomena. From a biological point of view, the drab, severe metropolitan world of mortar, steel, and machines constitutes a relatively simple environment, and the sharp division of labor developed by the modern urban economy imposes extremely limited, monotonous occupational activities on many of the individuals who make their livelihood in a large city.

These have not always been the characteristics of urban life. The metropolitan milieu represents a sharp departure from the forms and styles of life that prevailed in communities of the pre-industrial era. Early towns produced highly varied and colorful environments. Students of the medieval commune and the Renaissance city never fail to single out the humanizing artistic touch that the urban dweller gave to his home and to everyday articles. Craftsmen seldom permitted the function of an object to completely dominate its form. Decorativeness is to be found even in tools and weapons - objects which in our day are noteworthy for their purely functional design. This high sense of individual artistry was nourished by a vocational tradition that directed the workman to nearly every phase of the making of a product. The craftsman often prepared his raw material with his own hands, smelting his metals or tanning his leather. The great architects and engineers of the Renaissance not only designed a structure but also participated in its construction. The roundedness of the Renaissance man, which we look upon with so much envy today, was due in large part to a unity of mind and body, to a combination of thought and physical activity.

Early urban life was leisurely and relaxed. Craftsmen worked more or less in accordance with a pace established by physiological cycles, accelerating the tempo of their work during moments of energy and slowing down or halting entirely during periods of lethargy. The rate of physical activity was determined by the body's vitality rather than by external agencies, such as machines. Men did not try to "conserve" their energy and distribute it uniformly, as though it were an inorganic resource; human energy is seldom "conserved," in this simple, mechanical sense. Craftsman and artist worked by "fits and starts," giving themselves over to a task to the degree that their bodies were amenable to physical activity and artistic endeavor. Labor and art were seldom forced. The tempo of work varied, from hour to hour and day to day, with the changing vitality of the body.

The town developed in an agricultural matrix. Farms lay directly outside the city, not in a far-removed perimeter that the traveler could reach only after a long journey through suburbs and "exurbs." A short stroll carried the urban dweller from the market place, on which the principal cultural activities of the community were centered, into open fields and orchards. Farmer and city



man intermingled freely. In many cases, the urban dweller combined the work of a craftsman with that of a food grower, often maintaining a small garden inside the city walls to supply some of his own food. "One must not look at the narrow streets between the houses without remembering the open green, or the neatly checkered gardens, that usually stretched behind," observes Lewis Mumford.

Food staples were grown nearby, on farms that produced a variety of crops. As soon as a crop was harvested, it found its way quickly to the market place and from there to the urban consumer. The city dweller was never completely urbanized, in the narrow sense, as he is today. Gardening within the city and easy access to the countryside helped to fuse all aspects of urban and country life.

Early city life, to be sure, was burdened with many problems that have largely been solved by modern science and technology. Diet was severely restricted, especially in medieval times, and fresh foods were available only during the growing season. Sanitation remained primitive for centuries, although Mumford points out that the existence of open spaces in the medieval town "shows that sanitary arrangements were not necessarily as offensive as they have been pictured, nor vile smells as uniformly ubiquitous." Agricultural techniques were crude and few advances were made in transportation until railroads came into existence, but the early towns put the tools and the knowledge at their disposal to the best possible use. Life was usually serene. "One awoke in the medieval town to the crowing of the cock, the chirping of birds nesting under the eaves, or to the tolling of the hours in the monastery on the outskirts, perhaps to the chime of bells in the new bell tower. Song rose easily on the lips, from the plain chant of the monks to the refrains of the ballad singer in the market place, or that of the apprentice and the house-maid at work. As late as the seventeenth century, the ability to hold a part in a domestic choral song was rated by Pepys as an indispensable quality in a new maid. There were work songs, distinct for each craft, often composed to the rhythmic tapping or hammering of the craftsman himself. Fitz Stephens reported in the twelfth century that the sound of the water mill was a pleasant one amid the green fields of London. At night there would be complete silence' but for the stirring of animals and the calling of the hours by the town watch. Deep sleep was possible in the medieval towns, untainted by either human or mechanical noises."

Modern science has eliminated nearly all the difficulties that earlier urban communities faced. Owing to advanced means of transportation, the city dweller now enjoys a highly varied diet, and the metropolis receives abundant supplies of foods of all types the year round. Sanitation has reached a high technical level; the daily wastes of millions of people are removed without hazard to public health. And yet for every difficulty science has eliminated, the metropolis has created a new and greater problem in our manner of urban life.

The metropolis lacks nearly all the humanizing features of early urban life. In the medieval and Renaissance towns, intellectual activity and art were combined with physical labor; in the metropolis, intellectual activity, art, and physical labor are sharply separated. The civil engineer who designs a structure seldom participates in its construction; his counterpart in the field rarely engages in design. Architects like Frank Lloyd Wright, who concerned himself with nearly every phase of construction, are rarities. Most jobs in the metropolis are sedentary and monotonous. Some of the more rapidly growing occupations require very little mental or physical work; they are mindless as well as sedentary. Work of this kind is typified by the tasks of the billing-machine operator and the dictaphone pool typist, whose principal qualification is the ability to endure an excruciatingly vacuous routine.

The current occupational trend is toward an extreme simplification of the labor process. Work is fragmented, limited, and overspecialized. Modern industry has broken down many highly skilled crafts into repetitive tasks that the worker can perform mechanically, by habit, without losing time either in thinking or in changing tools. Work tends to become sedentary, not because the comfort of the worker is kept in mind, but because any unnecessary movement of the body tends to diminish output by interrupting the smooth, uniform flow of labor. The same trend is evident in intellectual and artistic work, where over-specialization tends to replace creative activity with mechanical operations. While many such jobs allow for considerable individual leeway, progressively fewer faculties are used or developed. In the worst cases, physical work is limited to a few dexterous operations of the fingers, mental work to a few dexterous operations of the mind.

Labor becomes highly intensive. The few faculties that are brought into play are employed at continually higher rates of speed. Work is viewed more as a function of habit than as the function of individual resources and talents whose use requires patience and tolerance. Thus, many jobs not only tend to restrict the use of certain parts of the body, but employ other parts excessively. Forms of work which once mobilized the human organism as a whole are supplanted by occupations that tax the eyes or the nerves. While the mind is dulled and the human musculature becomes flaccid, nerves become overly sensitive and raw. The anxieties and tensions created by intensive, sedentary work are reinforced by an exaggerated responsiveness of the nervous system as a whole.

The metropolis offers very little to counteract the oversimplification of the daily work routine. The urban dweller encounters few changes in color to awaken his visual senses; he receives virtually no respite from the artificial world in which he is immersed during working hours. Areas in which he can walk freely on soil and amid vegetation are disappearing; new dwellings, most of them noteworthy for their lack of architectural inspiration, are encroaching on the last open spaces in American cities. Public parks are likely to be congested during the day, and in the evening they often attract delinquent elements, whose presence discourages the respectable urban dweller from venturing into their precincts. American urban life has retreated indoors. This retreat is due partly to the erosion of human solidarity in large cities, partly to the seductive powers of the mass media. The average urban dweller is likely to pursue the same insensate, sedentary way of life during his leisure time that he follows during his working hours.

Many aspects of metropolitan life, while trivial in themselves, aggravate the effects of urban modes of work. The nervous strain that the city dweller feels at his job begins to gather within him even before he gets to work. He encounters inconveniences, rudeness, and congestion on public conveyances; he is beleaguered by countless small anxieties, many of which seldom rise to the level of consciousness. An all-pervasive irritation collects within him on his way to work, at work, between working hours, and on the way home. Mechanical noises are everywhere. They invade even the hours of sleep as a result of the growing web of highways that reaches into every part of the city. Advertising media assail the senses with garish images and sounds; their message is crude and elemental, designed to startle and perhaps to shock the viewer into a response. Recreation seldom furnishes the average urban dweller with the experiences denied to him in the daily bustle of life - moments of genuine serenity, silence, and gentle changes of scene. More often than not, urban recreation merely removes him temporarily from the afflictions of his environment without replenishing his reserves. It provides him with surcease from anxiety and nervous strain rather than with restoration of vitality.

Unfortunately, these problems are no longer confined to the city. The metropolis establishes the social standards of the entire country. Owing to its commanding economic and cultural position, it sets the pace of national life and establishes nearly all the criteria of national taste. Many distinctively urban forms of work and play have invaded the most remote rural areas of the United States, where they generate the same stresses in the villager and farmer that they do in the city dweller. The nature of agricultural work, moreover, is changing. As farming becomes increasingly industrialized, diversified physical work is reduced to a minimum by machines and one-crop agriculture. Although the farmer still pursues a less hurried way of life than his urban cousin, he is often beleaguered by even greater economic problems. Both in the city and on the land, a new type of man seems to be emerging. He is a nervous, excitable, and highly strained individual who is burdened by continual personal anxieties and mounting social insecurity.

## Stress and Chronic Illness

What are the effects of persistent emotional stress on human health?

Fifty years ago this question would have seemed irrelevant to the goals of medical research. The principal illnesses of the day were ascribed to the aging process, to a variety of "mechanical defects," such as blockages and ruptures, to a poor genetic endowment, and to bacterial infection. Germs satisfied the need for precise explanations of disease. They entered the body in a limited number of ways; they could be isolated, cultured, and tested on animals and human volunteers. With further knowledge, it was believed, all the effects produced by harmful bacteria would be understood and eventually controlled by some form of therapy. Emotional stress, on the other hand, was vague. It seemed to represent a generalized response on the part of the body to countless, often intangible stimuli. Although medicine was not unaware of the fact that emotional disturbances influenced the functioning of the heart and gastrointestinal tract, there seemed little reason to believe that stress played a causal role in the major diseases of man. (To cite a few exceptions: As early as the 1870's Dr. Jacob Mendes Da Costa described a syndrome which has since acquired the name of cardiac neurosis. Certain digestive disturbances were also recognized as being influenced by the emotional state of a patient, but these were often minor in nature.)

As chronic illnesses began to gain in importance, however, it became evident that the earlier approach was inadequate. Many arthritic conditions, for example, could not be explained by infection. Beginning slowly and insidiously, arthritis often produced in the end a hopelessly crippled, bedridden patient who faced a lifetime of pain and inactivity. At the same time, such words as "strain" and "anxiety" began to acquire real physiological meaning, denoting conditions that involved glandular conditions, biochemical changes in tissues, and involuntary activity of the nervous system. It was soon found that these physiological changes could produce or alleviate many of the symptoms associated with the common chronic diseases of our time.

A growing number of physicians now agree that emotional stress is a very important disease-promoting factor. It is safe to say that some disorders, such as peptic ulcers, arise primarily from anxiety and tension. During the latter part of the nineteenth century, peptic ulcers were regarded as a relatively uncommon disorder, and there arose very confused explanations of what caused the illness. Physicians generally believed that it occurred more frequently in women than in men, it was looked upon as a disorder primarily of "chlorotic," or anemic, girls. In the medical textbooks of the day, discussions of peptic ulcers were confined to descriptions of symptoms and

dietary therapy. With the passing years, however, the disease became a widespread and serious problem. Today, peptic ulcers afflict about 1/4 million Americans; each year nearly 400,000 are disabled for more than a week. Although a case of ulcers may often arouse a great deal of levity, the disease can reach grave proportions. About ten thousand Americans die of peptic ulcers every year. According to data compiled by the U. S. National Health Survey of 1957-9, the overwhelming majority of ulcer victims (73 per cent) are men. More cases appear in the thirty-five-to-forty-four age group-the years of greatest business and vocational activity - than in any other ten-year period of life.

Emotional stress is also deeply implicated in disorders of the blood vessels and the heart. "Physicians have long felt that the rapid pace of modern civilization might somehow be contributing to the development of heart disease," notes a report by the National Heart Institute. "The man who develops coronary artery disease is very frequently a hard-driving individual living in a state of more or less constant tension. In recent years evidence has accumulated that one way in which nervous tension may accelerate the development of coronary artery disease is through an elevation of the [blood] serum cholesterol level."

The evidence is impressive. In 1957, Friedman, Rosenman, and Carroll, of Mount Zion Hospital in San Francisco, began a study of the serum cholesterol level and blood-clotting time in forty male accountants during and after the tax season - sharply contrasting periods of high and low occupational stress. Blood was taken from the accountants twice weekly from January to June, and detailed records were kept of weight, diet, and changing work loads. "When studied individually," the investigators report, "each subject's highest serum cholesterol consistently occurred during severe occupational or other stress, and his lowest at times of minimal stress. The results could not be ascribed to any changes of weight, exercise, or diet. Marked acceleration of blood clotting time consistently occurred at the time of maximum occupational stress, in contrast to normal blood clotting during periods of respite."

Studies of a similar nature have been made of medical students during examination week. In 1958 a report of P. T. Wertlake at the College of Medical Evangelists in Los Angeles showed that the average serum cholesterol level of the students rose 11 percent during the four-day period in which they took school tests. The investigators found that nearly half of the students responded to the stress situation with increases ranging from 16 to 137 milligram per cent over a mean control level of 213. The serum cholesterol level of one student rose from an average control level of 259 milligram percent prior to the school examinations to a peak of 536 during one of the examination days - an increase of more than 100 percent. It would be wrong to suppose, however, that our knowledge of the link between emotional stress and illness is based entirely on statistical findings. During the past two decades, researchers have discovered a number of the biochemical effects that persistent anxiety produces in the human body. Attention has focused primarily on the adrenal glands, which cap the kidneys. The surface layer, or cortex, of these glands produces a number of highly potent regulatory chemical substances, or hormones. The cortical hormones, or corticoids, help the body to ward off disease and resist the effects of physical damage. A number of adrenal corticoids (aldosterone and DOC, for example) promote inflammation - the heat, swelling, and redness with which tissues react to common injuries. Although inflammation protects the body from bacterial invasion by "walling off" an injured area, the inflammatory process would go too far if it were not for anti-inflammatory corticoids, such as cortisone, which limit the process and prevent it from becoming needlessly widespread. The output of cortisone, in turn, is stimulated by ACTH, a hormone produced by the pituitary gland, situated at the base of the

skull. The control of the pro-inflammatory corticoids, and of the anti-inflammatory corticoids. If the balance in the secretion of these three types of hormones is altered, the inflammatory process may damage parts of the body.

Secretions of ACTH and the corticoids are influenced by the emotional state of the individual as well as by physical injury. This discovery has aroused strong suspicions that the corticoids and, by inference, persistent nervous strain, anxiety, and emotional conflicts play important roles in the occurrence of certain chronic disorders. In a review of the literature on rheumatoid arthritis and stress, Leon Hellman has suggested that "a more subtle form of stress in the guise of emotional conflicts is implicated in changes of the pituitary-adrenal system so as to render it less responsive or to alter the balance between various adrenal hormones secreted. A patient with rheumatoid arthritis would cure himself if his hypothalamus [a nerve center in the forebrain] and pituitary would interlock to increase the secretion of ACTH..." According to Hellman, it is quite possible that the production of ACTH is inhibited by a "neural block" arising from deep-seated emotional conflicts. Both ACTH and cortisone have been used with considerable success in treating arthritic disorders. The hormones alleviate rheumatoid symptoms so dramatically that hopelessly crippled, bedridden arthritics have been restored to almost complete use of their limbs.

The adrenal corticoids, however, influence more than the inflammatory process. They exercise extensive control over the level of minerals and sugar (glucose) in the blood. An imbalance in corticoid secretion is likely to have far-reaching effects on the body's metabolism and on organs that are commonly damaged by metabolic disorders, notably the heart and kidneys. By administering the pro-inflammatory hormone DOC to white Leghorn chicks, for example, Hans Selye and his coworkers at the University of Montreal were able to produce degenerative changes in the kidneys, with ensuing high blood pressure, hardening of the blood vessels, and cardiac disease. During the course of the experiment, the DOC treated chicks "began to drink much more water than the controls which were not given the hormone, and - gradually they developed a kind of dropsy. Their bodies became enormously swollen with fluid accumulations under the skin and they began to breathe with difficulty gasping for air, just like certain cardiac patients." By degrees, Selye's results and those of other researchers in the field began to include a large number of common chronic illnesses. Pro- and anti-inflammatory corticoids, it was found, seem to play roles of varying importance in diabetes, thyroid disorders, peptic ulcers, and psychic disturbances. The anti-inflammatory corticoids have been very useful in combating many of these illnesses. Cortisone frequently produces striking though temporary remissions in cases of acute leukemia, and the surgical removal of the adrenal glands often inhibits the growth of certain forms of cancer.

Selye has developed a general theory of stress from the data on the interplay of adrenal hormones. Stress consists of the physical changes within an organism which are caused by any environmental stimulus, whether it be heat, cold, infection, or a chemical irritant, and by the emotional disturbances we encounter in man. All living things have an adaptive mechanism that produces changes in the organism in response to changes in its environment. The adrenal corticoids in man and higher animals are essentially chemical agents that compel a living thing to respond internally to external stimuli. Every stimulus, desirable or harmful, produces a general stress reaction. Stress, in effect, is an important part of life.

But stress always results in a certain amount of "wear and tear" on the organism. "Many people believe that, after they have exposed themselves to very stressful activities, a rest can restore them to where they were before," Selye writes. "This is false. Experiments on animals have clearly

shown that each exposure leaves an indelible scar, in that it uses up reserves of adaptability which cannot be replaced. It is true that immediately after some harassing experience, rest can restore us almost to the original level of fitness by eliminating acute fatigue. But the emphasis is on the word almost. Since we constantly go through periods of stress and rest during life, just a little deficit of adaptation energy every day adds up-it adds up to what we call aging."

No one, to be sure, can eliminate the "wear and tear" of life, but a reasonably clear distinction can be made between the "stress of life" and stress that results in ill health. Stress that results in ill health is severe, persistent, and one-sided. Selye has demonstrated that if stress is too severe, the resistance and life span of the organism are drastically reduced. An experimental rat may adapt itself for a time to a strong irritant, but the adaptation is made at a high price; longevity is decreased and general resistance is seriously impaired. If the animal is exposed to even minor but persistent stress, comparable to the "low-grade" nervous tension and anxiety usually found in modern urban man, it pays a similar price for adaptation. The animal is easily injured by irritants that ordinarily do not produce serious physical damage. The interplay of stress responses is so complex that the reader must turn to Selye's own work, *The Stress of Life*, for a detailed discussion. In nearly all cases of severe or persistent stress, Selye has found evidence of thickened arteries, heart abnormalities, kidney damage, and increased blood pressure.

But Selye's work also demonstrates that stress need not be harmful, provided it is balanced and varied. A sheltered, sedentary life that lacks a variety of stimuli produces an undeveloped, often inadequate stress mechanism as well as an undeveloped personality. A sheltered person has great difficulty in coping with many of the stimuli and irritants inevitably encountered in the normal course of life. If there is any notion that sums up Selye's "stress of life" theory, it is the "pre-scientific" intuition that variety and balance - emotional, physical, and intellectual - are the bases not only for true individuality but for lasting health.

Selye's plea for variety in life, however, rests on a well-thought-out hypothesis. Man, as a complex, multicellular animal, is composed of many organs and systems, each of which bears a different amount of stress. The organs that compose his body do not "wear out" evenly. Death invariably comes "because one vital part has worn out too early in proportion to the rest of the body... The lesson seems to be that, as far as man can regulate his life by voluntary actions, he should seek to equalize stress throughout his being, by what we have called deviation, the frequent shifting-over of work from one part to the other. The human body-like the tires on a car, or the rug on a floor-wears longest when it wears evenly. We can do ourselves a great deal of good in this respect by just yielding to our natural cravings for variety in everyday life. We must not forget that the more we vary our actions the less any one part suffers from attrition."

Conceivably, an informed individual can try to cultivate a mature outlook that will lend distance to the petty irritations produced by the urban milieu. If circumstances permit, he can establish a personal regimen of after-work exercise and frequent excursions to the countryside. But on the whole, the metropolis exposes him to limited, intense occupational stimuli that produce an equally limited, intense stress response. A few organs continue to bear nearly the entire burden of daily life. Organs and systems that are not activated by modern forms of work and play are likely to be sheltered by the "conveniences" that the city affords. "One might question whether stress is peculiarly characteristic of our sheltered civilization, with all its comforts and amenities," observe P. C. Constantinides and Niall Carey in a general discussion of Selye's work. "Yet these very protections - modern laborsaving devices, clothing, heating - have rendered us all the more vulnerable and sensitive to the slightest stress. What was a mild stress to our forebears

now frequently represents a minor crisis. Moreover, the frustrations and repressions arising from emotional conflicts in the modern world, economic and political insecurity, the drudgery associated with many modern occupations - all these represent stresses as formidable as the most severe physical injuries."

## **The Problems of Overurbanization**

A number of urban problems have arisen that no city dweller can hope to solve or even meliorate on his own; they can be solved only by the community as a whole. One such problem, urban air pollution, has become very widespread and constitutes a serious hazard to human health. "Millions of citizens are living in an air ocean that is, on good evidence, unhealthy to breathe," observes Herman E. Hilleboe, New York State Commissioner of Health. "Cities with the heaviest pollution load tend to rank high both in death and incidence rates for a number of diseases. This includes heart disease and cancer, the ranking killers and disablers of our time." Among the new pollutants that will soon be added to our environment, Hilleboe warns, are "byproducts from petroleum and from synthetic materials spawned by our fast-growing nuclear technology and from high-energy solid and liquid fuels. We are creating a new environment but we have not as yet done what is necessary to make this environment healthful and habitable for its people. Here again it is difficult to dramatize the matter of air pollution."

The problem has been dramatized by cases in which air pollution reached the proportions of an emergency, comparable in many ways to an epidemic. Until fairly recently, serious cases of air pollution usually occurred in highly industrialized river valleys. Two such cases - one in the Meuse Valley in Belgium in 1930, which claimed sixty lives, and the other in Donora, Pennsylvania, in 1948, which killed twenty people - were due primarily to toxic fumes from metallurgical plants. To some degree, both could be regarded as industrial accidents, which could have been averted if suitable measures had been taken to control the effluents of local mills. A much greater respect for the potentially disastrous consequences of air pollution was created by the smog that descended upon London, a predominantly commercial city, during December 1952. Although the episode was brief, the daily death rate reached very high levels, comparable to those of London's cholera epidemic in 1854 and its influenza epidemic in 1918-19.

At dawn on Friday, December 5, the air in London began to thicken perceptibly. Unusual weather conditions caused a heavy smog of urban pollutants to linger over the city for four days. During the first twenty-four hours the death rate doubled, the total for the day reaching 400. The next day, Saturday, it rose to 600, and on each of the two following days, Sunday and Monday, it soared to 900, although business and industrial activity was suspended on Sunday. On Tuesday, when the smog had already begun to lift, the number of deaths was 800, and the death rate remained high for several weeks thereafter.

The London smog claimed at least 4,000 lives. The majority of deaths occurred among infants and elderly people, but William P. Dowie Logan, Britain's chief medical statistician, emphasizes that "it was by no means confined to the very young or the very old." The death rate in the fifteen-to-forty-four age group increased about 50 per cent. Deaths from coronary heart disease rose from 118 in the seven-day period immediately preceding the incident to 281 in the week that followed it, while deaths from bronchitis soared from 76 to 704, almost a tenfold increase.

The possibility that a lethal smog comparable to the one that descended on London, will develop somewhere in the United States cannot be excluded. If the word "smog" is defined as air pollution that produces haziness in the atmosphere and irritation of the eyes, nose, and throat, then many American communities experience smog. The situation in Los Angeles is notoriously bad; the city is afflicted with fifty to seventy days of smog every year. Smog is found to a lesser extent in New York, Washington, Philadelphia, Boston, and other coastal metropolitan areas of the United States. The differences between smog in England and smog in the United States are due primarily to the differences in the irritants that pervade the air of the two countries. Air pollution in London is caused mainly by the combustion of coal whereas the principal irritants in Los Angeles are produced by the combustion of petroleum products. Experts have emphasized, however, that "in the London episode the air pollutants, when considered in terms of their human effects, closely resembled those present in the air of many large urban areas. These pollutants were quite similar to those of many other urban areas in that they are irritating to the exposed living membranes (of the eyes, nose, throat and respiratory tract). For example although Los Angeles air pollution is chemically different from that of London the two resemble each other in their effects on man since each causes irritation of exposed living membranes."

Ordinarily, smog is episodic and localized. In the long run, a more serious problem is posed by persistent, low-grade air pollution, which is often imperceptible to the senses and changes relatively little from day to day. This form of air pollution is very widespread in the United States. Nearly 10,000 communities, containing the overwhelming majority of the American people, have persistent air pollution problems. According to a recent report by the New York State Air Pollution Control Board: "Of the state's 40 communities with populations of more than 25,000, only one had negligible air pollution. The combined survey data show that approximately three-fifths of the communities of 5,000 to 25,000 population and about one third of those with less than 5,000 people had major or minor air pollution." A survey of Texas by the U. S. Public Health Service showed that three quarters of the state's communities with populations of more than 10,000 had "objectionable air pollution."

Although patterns of air pollution vary from one community to another, it is generally agreed that the air in nearly all American cities contains a number of highly toxic substances, most of which are waste products of industrial plants, motor vehicles, and heating equipment. The solid particles in an urban atmosphere often include such highly toxic substances as lead, beryllium, and arsenic. Common air-borne gases and vapors include sulfuric-acid mist, sulfur dioxide, carbon monoxide, formaldehyde, oxides of nitrogen, ammonia, and scores of organic vapor contaminants. At least a hundred air pollutants have been identified, and the interaction of gases, vapors, and solid particles in the atmosphere produces many other compounds that have not been chemically analyzed. Several known toxicants that pollute the air are characterized by synergistic activity; they are more toxic together than when each is absorbed individually. For example, an effect that is more than additive is produced by the inhalation of carbon monoxide together with nitrogen oxide, two of the most common pollutants in the urban atmosphere.

The average individual breathes about 16,000 quarts of air daily. If he lives in an urban environment, his lungs receive about four times as many air contaminants as those of a rural dweller. John H. Ludwig, of the U. S. Public Health Service, suggests that repeated exposure to "relatively low levels of air pollution" may be involved in the development of chronic degenerative diseases, including skin and lung cancer, heart and vascular disorders, and chronic bronchitis. During periods when urban air pollution is at its height, the contaminants may worsen existing



chronic diseases, especially heart disorders, by interfering with the passage of oxygen through the membranes of the lungs into the blood stream. Certain air pollutants may combine with body proteins to form allergy-inducing, or allergenic, substances and lead to increasing sensitization and allergic reactions.

If the possible consequences of air pollution listed by Ludwig seem to be farfetched, let us enumerate some of the contaminants produced by the automobile, the principal source of air-borne toxicants in large American cities. Nearly 80 per cent of the pollutants that produce smog in Los Angeles come from motor vehicles. In burning 1,000 gallons of fuel, an automobile discharges 17 pounds of sulfur dioxide, about 18 pounds of aldehydes (estimated as formaldehyde), 25 to 75 pounds of oxides of nitrogen (estimated as nitrogen dioxide), 200 to 400 pounds of complex organic compounds, and over 3,000 pounds of carbon monoxide.

Sulfur dioxide is both an irritant and a poison. It is probably a major contributor to the high incidence of chronic bronchitis in England. There is evidence to indicate that a fairly low level of sulfur dioxide - "a level not infrequently found in air" - is sufficient to produce temporary spasms of the smooth muscles in the lungs. In "somewhat higher concentrations," the compound produces severe inflammation and peeling of the respiratory membranes. Formaldehyde is a corrosive poison that not only irritates the respiratory membranes but also affects the central nervous system, and nitrogen dioxide is a highly toxic gas that is extremely dangerous even in such relatively low quantities as 100 parts per million.

Several of the organic compounds produced by the combustion of gasoline and diesel oil are carcinogenic. This has been clearly established by Paul Kotin, of the University of California. When tarry material from the exhausts of motor vehicles was painted on laboratory mice, skin tumors appeared in 50 per cent of the animals. The largest amount of carcinogenic substances, according to Kotin's findings, is produced by slow-running and idling engines - that is, under conditions prevalent in areas with congested traffic (see pages 149-50).

A problem that has been largely ignored in the United States is the danger of chronic carbon monoxide poisoning. Until recently, conventional medical opinion held that carbon monoxide (CO) is rapidly removed from the blood stream. Few physicians regarded the enormous output of the gas by motor vehicles as a danger to public health. According to recent reports, however, carbon monoxide may be retained by the body for relatively long periods of time, perhaps as much as several weeks. The problem has aroused a great deal of concern in Europe, where the conviction is growing that chronic carbon monoxide poisoning is a serious hazard of the automobile era. In the United States, Richard Prindle, of the U. S. Public Health Service, emphasizes that "in a community in which carbon monoxide levels exist, 24 hours a day, seven days a week, for the lifetime of an individual, chronic CO poisoning is a distinct possibility." We need only consider the fact that smoking produces a definite level of carbon monoxide in the blood "to realize that coupling this with frequent, although fluctuating exposures to CO in the ambient air... might well lead to serious consequences in a large population."

Another problem that cannot be solved without the co-operation of the entire community is water pollution. Water is a traditional medium for the transmission of germs and toxic substances. During the past three generations vigorous efforts on the part of medical and public health officials have enormously reduced the hazard created by water-borne infectious agents, but today old problems of pollution are beginning to recur and new ones to appear, especially in communities that obtain the greater part of their drinking water from rivers. Although Americans tend to make a fetish of cleanliness, an appalling amount of untreated or inadequately treated urban

sewage is discharged into river water-water which is often taken up again for public consumption by communities downstream. Added to urban sewage are wastes from chemical factories, slaughterhouses, and metallurgical plants. Although sewage and industrial wastes have produced local public health crises in the past, the postwar expansion of cities and metropolitan areas is turning water pollution into a grave national problem, comparable in many respects to that created by urban air pollution.

Attempts by federal, state, and municipal authorities to control the contamination of our water are complicated by frequent changes in the composition of industrial and urban wastes. Today drinking water may contain a wide variety of new bleaches, detergents, petrochemical and metallurgical wastes, insecticides, dyes, and radioactive compounds. Few if any of these contaminants are removed by ordinary methods of water purification. Rolf Eliassen, of the Massachusetts Institute of Technology, points out that the "exotic organic chemicals" discharged by petrochemical plants into streams "are not even detected by present conventional means of water analysis." Neither industry nor pollution-control laboratories have been able to form a reliable picture of the long-range effects of the newer pollutants on public health. "Let us all be honest with ourselves," declares Robert A. Kehoe. "Specifications for human health and welfare, in relation to the common contaminants of many of our sources of water, do not exist, and we shall not be able to deal effectively with this problem of public health until they can be formulated on sound physiological facts."

At the same time, the traditional problem of waterborne infections is gaining greater significance. Many cases of acute illness are being attributed to polluted drinking water. To cite a few examples: In 1957 the number of cases of infectious hepatitis began to increase markedly in Nebraska. The disease, an acute inflammation of the liver, was found predominantly in the eastern part of the state. The outbreaks occurred primarily in urban communities that obtain their drinking water from the highly polluted Missouri River. Although most public health officials tend to be extremely cautious in their comments, Nebraskan authorities made no attempt to conceal their suspicion that the increase in hepatitis cases was due to drinking water contaminated by sewage from upstream communities. Similar explanations have been given for polio epidemics in Salt Lake City and in Edmonton, capital of the Canadian province of Alberta. (Much of the evidence pointing to polluted water as the cause of these outbreaks is circumstantial, but there is no longer any doubt that hepatitis can be communicated by water as well as by personal contact. The Edmonton outbreak suggests that poliomyelitis can also be transmitted by water. Edmonton obtains its drinking water from the Saskatchewan River and the epidemic could be related to a failure of the sewage system at a town upstream.) Both diseases are caused by viruses that are found in human feces and sewage.

True, water-borne diseases and, in some communities, urban air pollution have been more serious in the past than they are today. In 1832, Asiatic cholera spread from Quebec to New York City, where it claimed thousands of lives. Cholera persisted in the city for decades before it was eradicated. Typhoid fever, another waterborne disease, was found everywhere during the last century. Owing to improved methods of public sanitation, the incidence of the disease is now negligible. Similarly, many of the worst pockets of urban air pollution are being "cleared up," to the extent of eliminating some of the dense soot and smoke. The cloud of industrial soot that began to descend on Pittsburgh as early as the 1860's has been lifted. Although Pittsburgh does not enjoy pure air, a reduction has been achieved in the more offensive pollutants that once filled the city's atmosphere. Air pollution programs have gained ground primarily against the smoke

and grime of the old Industrial Revolution, just as social reform has scored its greatest triumphs over illiteracy and child labor.

Since World War II, however, there has been a new industrial revolution, and the problems of urban life have acquired new dimensions. On the one hand, the sources of urban pollution have increased in number and variety; many pollutants, such as those produced by the automobile, are difficult to manage, even where everyone is willing to co-operate on the problem. On the other hand, metropolitan regions are being burdened beyond their capacity to cope with air pollutants and to meet the need for clean water. Their waterways and atmosphere are expected to absorb a staggering quantity of waste products from industrial plants, homes, and vehicles. Currently the United States must dispose of over 18 billion pounds of sewage solids every year, an increase of 70 per cent in the past two decades. The water table in many areas of the United States is being lowered by the voracious demands of highly concentrated populations and expanding industries. At the same time that the number of pollutants has increased, the ecological preconditions for wholesome air and plentiful water are being undermined. A major disequilibrium is arising between town and country, industry and the biotic environment, and population and regional resources.

Rene Dubos, of the Rockefeller Institute for Medical Research, places smog among the major environmental factors that have unleashed the "Apocalyptic horsemen" of modern disease. According to Dubos, St. John the Divine's vision on the isle of Patmos is symbolic of present-day urban and industrial life. The first horsemen of the Apocalypse to be seen by the saint were Famine and Pestilence. "Then another, even more terrifying visitation was sent by the angered Deity," Dubos recalls. "After the fifth angel had sounded his trumpet he opened the bottomless pit and 'there arose a smoke out of the pit, as the smoke of a great furnace; and the sun and the air were darkened by reason of the smoke of the pit.' And out of the bottomless pit came the scorpions that did not kill men but tormented them for five months before final destruction came 'by the fire, and by the smoke and by the brimstone.' The time of fulfillment of the Apocalypse may not be far off."

Dubos is not being overly dramatic. We are producing a new spectrum of environmental hazards whose full effects still await the passage of time. The trends are not encouraging. "Many diseases that are thought to be associated with, or caused by, air pollution have been increasing over the years," Prindle writes. "Included among these are the respiratory cancers, emphysema, chronic bronchitis, and cor pulmonale. (Emphysema is a pulmonary disorder that often leads to cor pulmonale, a common form of heart disease. Emphysema has become a major disease in London, ranking third (following heart diseases and cancer) as a cause of death among middle-aged males. The increase in emphysema cases, both in London and Los Angeles, is attributed by many medical authorities to air pollution.) If air pollution continues to increase, one can only conjecture that this rising incidence of disease will continue and that the effect upon the health of the nation - and over the technologically - expanding world - may be severely augmented. The overall effect of air pollution on the economy, the health, and the welfare of the people may become a disaster."

The effects of air pollution on public health will be difficult to judge for many years to come. A large number of adults straddle two worlds. They were born and raised in communities that have only recently acquired the features of metropolitan life. The early years of their lives were spent in the pre-nuclear age. But it is difficult to ignore the portents found in the high incidence

of chronic diseases in all age groups of the population. Without a basic solution to the problems of urban life, Dubos's apprehension may prove to be amply justified.

Man's environment attains a high degree of simplification in the modern metropolis. At first this may seem surprising: We normally associate metropolitan life with a diversity of individual types and with variety and subtlety in human relations. But diversity among men and complexity in human relations are social and cultural phenomena. From a biological point of view, the drab, severe metropolitan world of mortar, steel, and machines constitutes a relatively simple environment, and the sharp division of labor developed by the modern urban economy imposes extremely limited, monotonous occupational activities on many of the individuals who make their livelihood in a large city.

These have not always been the characteristics of urban life. The metropolitan milieu represents a sharp departure from the forms and styles of life that prevailed in communities of the pre-industrial era. Early towns produced highly varied and colorful environments. Students of the medieval commune and the Renaissance city never fail to single out the humanizing artistic touch that the urban dweller gave to his home and to everyday articles. Craftsmen seldom permitted the function of an object to completely dominate its form. Decorativeness is to be found even in tools and weapons-objects which in our day are noteworthy for their purely functional design. This high sense of individual artistry was nourished by a vocational tradition that directed the workman to nearly every phase of the making of a product. The craftsman often prepared his raw material with his own hands, smelting his metals or tanning his leather. The great architects and engineers of the Renaissance not only designed a structure but also participated in its construction. The roundedness of the Renaissance man, which we look upon with so much envy today, was due in large part to a unity of mind and body, to a combination of thought and physical activity.

Early urban life was leisurely and relaxed. Craftsmen worked more or less in accordance with a pace established by physiological cycles, accelerating the tempo of their work during moments of energy and slowing down or halting entirely during periods of lethargy. The rate of physical activity was determined by the body's vitality rather than by external agencies, such as machines. Men did not try to "conserve" their energy and distribute it uniformly, as though it were an inorganic resource; human energy is seldom "conserved," in this simple, mechanical sense. Craftsman and artist worked by "fits and starts," giving themselves over to a task to the degree that their bodies were amenable to physical activity and artistic endeavor. Labor and art were seldom forced. The tempo of work varied, from hour to hour and day to day, with the changing vitality of the body.

The town developed in an agricultural matrix. Farms lay directly outside the city, not in a far-removed perimeter that the traveler could reach only after a long journey through suburbs and "exurbs." A short stroll carried the urban dweller from the market place, on which the principal cultural activities of the community were centered, into open fields and orchards. Farmer and city man intermingled freely. In many cases, the urban dweller combined the work of a craftsman with that of a food grower, often maintaining a small garden inside the city walls to supply some of his own food. "One must not look at the narrow streets between the houses without remembering the open green, or the neatly checkered gardens, that usually stretched behind," observes Lewis Mumford.

Food staples were grown nearby, on farms that produced a variety of crops. As soon as a crop was harvested, it found its way quickly to the market place and from there to the urban consumer.

The city dweller was never completely urbanized, in the narrow sense, as he is today. Gardening within the city and easy access to the countryside helped to fuse all aspects of urban and country life.

Early city life, to be sure, was burdened with many problems that have largely been solved by modern science and technology. Diet was severely restricted, especially in medieval times, and fresh foods were available only during the growing season. Sanitation remained primitive for centuries, although Mumford points out that the existence of open spaces in the medieval town "shows that sanitary arrangements were not necessarily as offensive as they have been pictured, nor vile smells as uniformly ubiquitous." Agricultural techniques were crude and few advances were made in transportation until railroads came into existence, but the early towns put the tools and the knowledge at their disposal to the best possible use. Life was usually serene. "One awoke in the medieval town to the crowing of the cock, the chirping of birds nesting under the eaves, or to the tolling of the hours in the monastery on the outskirts, perhaps to the chime of bells in the new belltower. Song rose easily on the lips, from the plain chant of the monks to the refrains of the ballad singer in the market place, or that of the apprentice and the house-maid at work. As late as the seventeenth century, the ability to hold a part in a domestic choral song was rated by Pepys as an indispensable quality in a new maid. There were work songs, distinct for each craft, often composed to the rhythmic tapping or hammering of the craftsman himself. Fitz Stephens reported in the twelfth century that the sound of the water mill was a pleasant one amid the green fields of London. At night there would be complete silence' but for the stirring of animals and the calling of the hours by the town watch. Deep sleep was possible in the medieval towns, untainted by either human or mechanical noises."

Modern science has eliminated nearly all the difficulties that earlier urban communities faced. Owing to advanced means of transportation, the city dweller now enjoys a highly varied diet, and the metropolis receives abundant supplies of foods of all types the year round. Sanitation has reached a high technical level; the daily wastes of millions of people are removed without hazard to public health. And yet for every difficulty science has eliminated, the metropolis has created a new and greater problem in our manner of urban life.

The metropolis lacks nearly all the humanizing features of early urban life. In the medieval and Renaissance towns, intellectual activity and art were combined with physical labor; in the metropolis, intellectual activity, art, and physical labor are sharply separated. The civil engineer who designs a structure seldom participates in its construction; his counterpart in the field rarely engages in design. Architects like Frank Lloyd Wright, who concerned himself with nearly every phase of construction, are rarities. Most jobs in the metropolis are sedentary and monotonous. Some of the more rapidly growing occupations require very little mental or physical work; they are mindless as well as sedentary. Work of this kind is typified by the tasks of the billing-machine operator and the dictaphone pool typist, whose principal qualification is the ability to endure an excruciatingly vacuous routine.

The current occupational trend is toward an extreme simplification of the labor process. Work is fragmented, limited, and overspecialized. Modern industry has broken down many highly skilled crafts into repetitive tasks that the worker can perform mechanically, by habit, without losing time either in thinking or in changing tools. Work tends to become sedentary, not because the comfort of the worker is kept in mind, but because any unnecessary movement of the body tends to diminish output by interrupting the smooth, uniform flow of labor. The same trend is evident in intellectual and artistic work, where over-specialization tends to replace creative activ-

ity with mechanical operations. While many such jobs allow for considerable individual leeway, progressively fewer faculties are used or developed. In the worst cases, physical work is limited to a few dexterous operations of the fingers, mental work to a few dexterous operations of the mind.

Labor becomes highly intensive. The few faculties that are brought into play are employed at continually higher rates of speed. Work is viewed more as a function of habit than as the function of individual resources and talents whose use requires patience and tolerance. Thus, many jobs not only tend to restrict the use of certain parts of the body, but employ other parts excessively. Forms of work which once mobilized the human organism as a whole are supplanted by occupations that tax the eyes or the nerves. While the mind is dulled and the human musculature becomes flaccid, nerves become overly sensitive and raw. The anxieties and tensions created by intensive, sedentary work are reinforced by an exaggerated responsiveness of the nervous system as a whole.

The metropolis offers very little to counteract the oversimplification of the daily work routine. The urban dweller encounters few changes in color to awaken his visual senses; he receives virtually no respite from the artificial world in which he is immersed during working hours. Areas in which he can walk freely on soil and amid vegetation are disappearing; new dwellings, most of them noteworthy for their lack of architectural inspiration, are encroaching on the last open spaces in American cities. Public parks are likely to be congested during the day, and in the evening they often attract delinquent elements, whose presence discourages the respectable urban dweller from venturing into their precincts. American urban life has retreated indoors. This retreat is due partly to the erosion of human solidarity in large cities, partly to the seductive powers of the mass media. The average urban dweller is likely to pursue the same insensate, sedentary way of life during his leisure time that he follows during his working hours.

Many aspects of metropolitan life, while trivial in themselves, aggravate the effects of urban modes of work. The nervous strain that the city dweller feels at his job begins to gather within him even before he gets to work. He encounters inconveniences, rudeness, and congestion on public conveyances; he is beleaguered by countless small anxieties, many of which seldom rise to the level of consciousness. An all-pervasive irritation collects within him on his way to work, at work, between working hours, and on the way home. Mechanical noises are everywhere. They invade even the hours of sleep as a result of the growing web of highways that reaches into every part of the city. Advertising media assail the senses with garish images and sounds; their message is crude and elemental, designed to startle and perhaps to shock the viewer into a response. Recreation seldom furnishes the average urban dweller with the experiences denied to him in the daily bustle of life—moments of genuine serenity, silence, and gentle changes of scene. More often than not, urban recreation merely removes him temporarily from the afflictions of his environment without replenishing his reserves. It provides him with surcease from anxiety and nervous strain rather than with restoration of vitality.

Unfortunately, these problems are no longer confined to the city. The metropolis establishes the social standards of the entire country. Owing to its commanding economic and cultural position, it sets the pace of national life and establishes nearly all the criteria of national taste. Many distinctively urban forms of work and play have invaded the most remote rural areas of the United States, where they generate the same stresses in the villager and farmer that they do in the city dweller. The nature of agricultural work, moreover, is changing. As farming becomes increasingly industrialized, diversified physical work is reduced to a minimum by machines and

one-crop agriculture. Although the farmer still pursues a less hurried way of life than his urban cousin, he is often beleaguered by even greater economic problems. Both in the city and on the land, a new type of man seems to be emerging. He is a nervous, excitable, and highly strained individual who is burdened by continual personal anxieties and mounting social insecurity.

#### Stress and Chronic Illness

What are the effects of persistent emotional stress on human health?

Fifty years ago this question would have seemed irrelevant to the goals of medical research. The principal illnesses of the day were ascribed to the aging process, to a variety of "mechanical defects," such as blockages and ruptures, to a poor genetic endowment, and to bacterial infection. Germs satisfied the need for precise explanations of disease. They entered the body in a limited number of ways; they could be isolated, cultured, and tested on animals and human volunteers. With further knowledge, it was believed, all the effects produced by harmful bacteria would be understood and eventually controlled by some form of therapy. Emotional stress, on the other hand, was vague. It seemed to represent a generalized response on the part of the body to countless, often intangible stimuli. Although medicine was not unaware of the fact that emotional disturbances influenced the functioning of the heart and gastrointestinal tract, there seemed little reason to believe that stress played a causal role in the major diseases of man. (To cite a few exceptions: As early as the 1870's Dr. Jacob Mendes Da Costa described a syndrome which has since acquired the name of cardiac neurosis. Certain digestive disturbances were also recognized as being influenced by the emotional state of a patient, but these were often minor in nature.)

As chronic illnesses began to gain in importance, however, it became evident that the earlier approach was inadequate. Many arthritic conditions, for example, could not be explained by infection. Beginning slowly and insidiously, arthritis often produced in the end a hopelessly crippled, bedridden patient who faced a lifetime of pain and inactivity. At the same time, such words as "strain" and "anxiety" began to acquire real physiological meaning, denoting conditions that involved glandular conditions, biochemical changes in tissues, and involuntary activity of the nervous system. It was soon found that these physiological changes could produce or alleviate many of the symptoms associated with the common chronic diseases of our time.

A growing number of physicians now agree that emotional stress is a very important disease-promoting factor. It is safe to say that some disorders, such as peptic ulcers, arise primarily from anxiety and tension. During the latter part of the nineteenth century, peptic ulcers were regarded as a relatively uncommon disorder, and there arose very confused explanations of what caused the illness. Physicians generally believed that it occurred more frequently in women than in men, it was looked upon as a disorder primarily of "chlorotic," or anemic, girls. In the medical textbooks of the day, discussions of peptic ulcers were confined to descriptions of symptoms and dietary therapy. With the passing years, however, the disease became a widespread and serious problem. Today, peptic ulcers afflict about 1/4 million Americans; each year nearly 400,000 are disabled for more than a week. Although a case of ulcers may often arouse a great deal of levity, the disease can reach grave proportions. About ten thousand Americans die of peptic ulcers every year. According to data compiled by the U. S. National Health Survey of 1957-9, the overwhelming majority of ulcer victims (73 per cent) are men. | More cases appear in the thirty-five-to-forty-four age group-the years of greatest business and vocational activity-than in any other ten-year period of life.

Emotional stress is also deeply implicated in disorders of the blood vessels and the heart. "Physicians have long felt that the rapid pace of modern civilization might somehow be con-

tributing to the development of heart disease," notes a report by the National Heart Institute. "The man who develops coronary artery disease is very frequently a hard-driving individual living in a state of more or less constant tension. In recent years evidence has accumulated that one way in which nervous tension may accelerate the development of coronary artery disease is through an elevation of the [blood] serum cholesterol level."

The evidence is impressive. In 1957, Friedman, Rosenman, and Carroll, of Mount Zion Hospital in San Francisco, began a study of the serum cholesterol level and blood-clotting time in forty male accountants during and after the tax season-sharply contrasting periods of high and low occupational stress. Blood was taken from the accountants twice weekly from January to June, and detailed records were kept of weight, diet, and changing work loads. "When studied individually," the investigators report, "each subject's highest serum cholesterol consistently occurred during severe occupational or other stress, and his lowest at times of minimal stress. The results could not be ascribed to any changes of weight, exercise, or diet. Marked acceleration of blood clotting time consistently occurred at the time of maximum occupational stress, in contrast to normal blood clotting during periods of respite."

Studies of a similar nature have been made of medical students during examination week. In 1958 a report of P. T. Werthake at the College of Medical Evangelists in Los Angeles showed that the average serum cholesterol level of the students rose 11 percent during the four-day period in which they took school tests. The investigators found that nearly half of the students responded to the stress situation with increases ranging from 16 to 137 milligram per cent over a mean control level of 213. The serum cholesterol level of one student rose from an average control level of 259 milligram percent prior to the school examinations to a peak of 536 during one of the examination days-an increase of more than 100 percent. It would be wrong to suppose, however, that our knowledge of the link between emotional stress and illness is based entirely on statistical findings. During the past two decades, researchers have discovered a number of the biochemical effects that persistent anxiety produces in the human body. Attention has focused primarily on the adrenal glands, which cap the kidneys. The surface layer, or cortex, of these glands produces a number of highly potent regulatory chemical substances, or hormones. The cortical hormones, or corticoids, help the body to ward off disease and resist the effects of physical damage. A number of adrenal corticoids (aldosterone and DOC, for example ) promote inflammation-the heat, swelling, and redness with which tissues react to common injuries. Although inflammation protects the body from bacterial invasion by "walling off" an injured area, the inflammatory process would go too far if it were not for anti-inflammatory corticoids, such as cortisone, which limit the process and prevent it from becoming needlessly widespread. The output of cortisone, in turn, is stimulated by ACTH, a hormone produced by the pituitary gland, situated at the base of the skull. The control of the pro-inflammatory corticoids, and of the anti-inflammatory corticoids. If the balance in the secretion of these three types of hormones is altered, the inflammatory process may damage parts of the body.

Secretions of ACTH and the corticoids are influenced by the emotional state of the individual as well as by physical injury. This discovery has aroused strong suspicions that the corticoids and, by inference, persistent nervous strain, anxiety, and emotional conflicts play important roles in the occurrence of certain chronic disorders. In a review of the literature on rheumatoid arthritis and stress, Leon Hellman has suggested that "a more subtle form of stress in the guise of emotional conflicts is implicated in changes of the pituitary-adrenal system so as to render it less responsive or to alter the balance between various adrenal hormones secreted. A patient with rheumatoid



arthritis would cure himself if his hypothalamus [a nerve center in the forebrain] and pituitary would interlock to increase the secretion of ACTH . . .” According to Hellman, it is quite possible that the production of ACTH is inhibited by a “neural block” arising from deep-seated emotional conflicts. Both ACTH and cortisone have been used with considerable success in treating arthritic disorders. The hormones alleviate rheumatoid symptoms so dramatically that hopelessly crippled, bedridden arthritics have been restored to almost complete use of their limbs.

The adrenal corticoids, however, influence more than the inflammatory process. They exercise extensive control over the level of minerals and sugar (glucose) in the blood. An imbalance in corticoid secretion is likely to have far-reaching effects on the body’s metabolism and on organs that are commonly damaged by metabolic disorders, notably the heart and kidneys. By administering the pro-inflammatory hormone DOC to white Leghorn chicks, for example, Hans Selye and his coworkers at the University of Montreal were able to produce degenerative changes in the kidneys, with ensuing high blood pressure, hardening of the blood vessels, and cardiac disease. During the course of the experiment, the DOCTreated chicks “began to drink much more water than the controls which were not given the hormone, and - gradually they developed a kind of dropsy. Their bodies became enormously swollen with fluid accumulations under the skin and they began to breathe with difficulty gasping for air, just like certain cardiac patients.” By degrees, Selye’s results and those of other researchers in the field began to include a large number of common chronic illnesses. Pro- and anti-inflammatory corticoids, it was found, seem to play roles of varying importance in diabetes, thyroid disorders, peptic ulcers, and psychic disturbances. The anti-inflammatory corticoids have been very useful in combating many of these illnesses. Cortisone frequently produces striking though temporary remissions in cases of acute leukemia, and the surgical removal of the adrenal glands often inhibits the growth of certain forms of cancer.

Selye has developed a general theory of stress from the data on the interplay of adrenal hormones. Stress consists of the physical changes within an organism which are caused by any environmental stimulus, whether it be heat, cold, infection, or a chemical irritant, and by the emotional disturbances we encounter in man. All living things have an adaptive mechanism that produces changes in the organism in response to changes in its environment. The adrenal corticoids in man and higher animals are essentially chemical agents that compel a living thing to respond internally to external stimuli. Every stimulus, desirable or harmful, produces a general stress reaction. Stress, in effect, is an important part of life.

But stress always results in a certain amount of “wear and tear” on the organism. “Many people believe that, after they have exposed themselves to very stressful activities, a rest can restore them to where they were before,” Selye writes. “This is false. Experiments on animals have clearly shown that each exposure leaves an indelible scar, in that it uses up reserves of adaptability which cannot be replaced. It is true that immediately after some harassing experience, rest can restore us almost to the original level of fitness by eliminating acute fatigue. But the emphasis is on the word almost. Since we constantly go through periods of stress and rest during life, just a little deficit of adaptation energy every day adds up-it adds up to what we call aging.”

No one, to be sure, can eliminate the “wear and tear” of life, but a reasonably clear distinction can be made between the “stress of life” and stress that results in ill health. Stress that results in ill health is severe, persistent, and one-sided. Selye has demonstrated that if stress is too severe, the resistance and life span of the organism are drastically reduced. An experimental rat may adapt itself for a time to a strong irritant, but the adaptation is made at a high price; longevity

is decreased and general resistance is seriously impaired. If the animal is exposed to even minor but persistent stress, comparable to the 'low-grade' nervous tension and anxiety usually found in modern urban man, it pays a similar price for adaptation. The animal is easily injured by irritants that ordinarily do not produce serious physical damage. The interplay of stress responses is so complex that the reader must turn to Selye's own work, *The Stress of Life*, for a detailed discussion. In nearly all cases of severe or persistent stress, Selye has found evidence of thickened arteries, heart abnormalities, kidney damage, and increased blood pressure.

But Selye's work also demonstrates that stress need not be harmful, provided it is balanced and varied. A sheltered, sedentary life that lacks a variety of stimuli produces an undeveloped, often inadequate stress mechanism as well as an undeveloped personality. A sheltered person has great difficulty in coping with many of the stimuli and irritants inevitably encountered in the normal course of life. If there is any notion that sums up Selye's "stress of life" theory, it is the "pre-scientific" intuition that variety and balance-emotional, physical, and intellectual-are the bases not only for true individuality but for lasting health.

Selye's plea for variety in life, however, rests on a well-thought-out hypothesis. Man, as a complex, multicellular animal, is composed of many organs and systems, each of which bears a different amount of stress. The organs that compose his body do not "wear out" evenly. Death invariably comes "because one vital part has worn out too early in proportion to the rest of the body... The lesson seems to be that, as far as man can regulate his life by voluntary actions, he should seek to equalize stress throughout his being, by what we have called deviation, the frequent shifting-over of work from one part to the other. The human body-like the tires on a car, or the rug on a floor-wears longest when it wears evenly. We can do ourselves a great deal of good in this respect by just yielding to our natural cravings for variety in everyday life. We must not forget that the more we vary our actions the less any one part suffers from attrition."

Conceivably, an informed individual can try to cultivate a mature outlook that will lend distance to the petty irritations produced by the urban milieu. If circumstances permit, he can establish a personal regimen of after-work exercise and frequent excursions to the countryside. But on the whole, the metropolis exposes him to limited, intense occupational stimuli that produce an equally limited, intense stress response. A few organs continue to bear nearly the entire burden of daily life. Organs and systems that are not activated by modern forms of work and play are likely to be sheltered by the "conveniences" that the city affords. "One might question whether stress is peculiarly characteristic of our sheltered civilization, with all its comforts and amenities," observe P. C. Constantinides and Niall Carey in a general discussion of Selye's work. "Yet these very protections-modern laborsaving devices, clothing, heating-have rendered us all the more vulnerable and sensitive to the slightest stress. What was a mild stress to our forebears now frequently represents a minor crisis. Moreover, the frustrations and repressions arising from emotional conflicts in the modern world, economic and political insecurity, the drudgery associated with many modern occupations-all these represent stresses as formidable as the most severe physical injuries."

#### The Problems of Overurbanization

A number of urban problems have arisen that no city dweller can hope to solve or even meliorate on his own; they can be solved only by the community as a whole. One such problem, urban air pollution, has become very widespread and constitutes a serious hazard to human health. "Millions of citizens are living in an air ocean that is, on good evidence, unhealthy to breathe," observes Herman E. Hilleboe, New York State Commissioner of Health. "Cities with the heaviest

pollution load tend to rank high both in death and incidence rates for a number of diseases. This includes heart disease and cancer, the ranking killers and disablers of our time.” Among the new pollutants that will soon be added to our environment, Hilleboe warns, are “byproducts from petroleum and from synthetic materials spawned by our fast-growing nuclear technology and from high-energy solid and liquid fuels. We are creating a new environment but we have not as yet done what is necessary to make this environment healthful and habitable for its people. Here again it is difficult to dramatize the matter of air pollution.”

The problem has been dramatized by cases in which air pollution reached the proportions of an emergency, comparable in many ways to an epidemic. Until fairly recently, serious cases of air pollution usually occurred in highly industrialized river valleys. Two such cases- one in the Meuse Valley in Belgium in 1930, which claimed sixty lives, and the other in Donora, Pennsylvania, in 1948, which killed twenty people-were due primarily to toxic fumes from metallurgical plants. To some degree, both could be regarded as industrial accidents, which could have been averted if suitable measures had been taken to control the effluents of local mills. A much greater respect for the potentially disastrous consequences of air pollution was created by the smog that descended upon London, a predominantly commercial city, during December 1952. Although the episode was brief, the daily death rate reached very high levels, comparable to those of London’s cholera epidemic in 1854 and its influenza epidemic in 1918-19.

At dawn on Friday, December 5, the air in London began to thicken perceptibly. Unusual weather conditions caused a heavy smog of urban pollutants to linger over the city for four days. During the first twenty-four hours the death rate doubled, the total for the day reaching 400. The next day, Saturday, it rose to 600, and on each of the two following days, Sunday and Monday, it soared to 900, although business and industrial activity was suspended on Sunday. On Tuesday, when the smog had already begun to lift, the number of deaths was 800, and the death rate remained high for several weeks thereafter.

The London smog claimed at least 4,000 lives. The majority of deaths occurred among infants and elderly people, but William P. Dowie Logan, Britain’s chief medical statistician, emphasizes that “it was by no means confined to the very young or the very old.” The death rate in the fifteen-to-forty-four age group increased about 50 per cent. Deaths from coronary heart disease rose from 118 in the seven-day period immediately preceding the incident to 281 in the week that followed it, while deaths from bronchitis soared from 76 to 704, almost a tenfold increase.

The possibility that a lethal smog comparable to the one that descended on London, will develop somewhere in the United States cannot be excluded. If the word “smog” is defined as air pollution that produces haziness in the atmosphere and irritation of the eyes, nose, and throat, then many American communities experience smog. The situation in Los Angeles is notoriously bad; the city is afflicted with fifty to seventy days of smog every year. Smog is found to a lesser extent in New York, Washington, Philadelphia, Boston, and other coastal metropolitan areas of the United States. The differences between smog in England and smog in the United States are due primarily to the differences in the irritants that pervade the air of the two countries. Air pollution in London is caused mainly by the combustion of coal whereas the principal irritants in Los Angeles are produced by the combustion of petroleum products. Experts have emphasized, however, that “in the London episode the air pollutants, when considered in terms of their human effects, closely resembled those present in the air of many large urban areas. These pollutants were quite similar to those of many other urban areas in that they are irritating to the exposed living membranes (of the eyes, nose, throat and respiratory tract). For example although Los An-

geles air pollution is chemically different from that of London the two resemble each other in their effects on man since each causes irritation of exposed living membranes.”

Ordinarily, smog is episodic and localized. In the long run, a more serious problem is posed by persistent, low-grade air pollution, which is often imperceptible to the senses and changes relatively little from day to day. This form of air pollution is very widespread in the United States. Nearly 10,000 communities, containing the overwhelming majority of the American people, have persistent air pollution problems. According to a recent report by the New York State Air Pollution Control Board: “Of the state’s 40 communities with populations of more than 25,000, only one had negligible air pollution. The combined survey data show that approximately three-fifths of the communities of 5000 to 25000 population and about one third of those with less than 5000 people had major or minor air pollution.” A survey of Texas by the U. S. Public Health Service showed that three quarters of the state’s communities with populations of more than 10000 had “objectionable air pollution.”

Although patterns of air pollution vary from one community to another, it is generally agreed that the air in nearly all American cities contains a number of highly toxic substances, most of which are waste products of industrial plants, motor vehicles, and heating equipment. The solid particles in an urban atmosphere often include such highly toxic substances as lead, beryllium, and arsenic. Common air-borne gases and vapors include sulfuric-acid mist, sulfur dioxide, carbon monoxide, formaldehyde, oxides of nitrogen, ammonia, and scores of organic vapor contaminants. At least a hundred air pollutants have been identified, and the interaction of gases, vapors, and solid particles in the atmosphere produces many other compounds that have not been chemically analyzed. Several known toxicants that pollute the air are characterized by synergistic activity; they are more toxic together than when each is absorbed individually. For example, an effect that is more than additive is produced by the inhalation of carbon monoxide together with nitrogen oxide, two of the most common pollutants in the urban atmosphere.

The average individual breathes about 16,000 quarts of air daily. If he lives in an urban environment, his lungs receive about four times as many air contaminants as those of a rural dweller. John H. Ludwig, of the U. S. Public Health Service, suggests that repeated exposure to “relatively low levels of air pollution” may be involved in the development of chronic degenerative diseases, including skin and lung cancer, heart and vascular disorders, and chronic bronchitis. During periods when urban air pollution is at its height, the contaminants may worsen existing chronic diseases, especially heart disorders, by interfering with the passage of oxygen through the membranes of the lungs into the blood stream. Certain air pollutants may combine with body proteins to form allergy-inducing, or allergenic, substances and lead to increasing sensitization and allergic reactions.

If the possible consequences of air pollution listed by Ludwig seem to be farfetched, let us enumerate some of the contaminants produced by the automobile, the principal source of air-borne toxicants in large American cities. Nearly 80 per cent of the pollutants that produce smog in Los Angeles come from motor vehicles. In burning 1,000 gallons of fuel, an automobile discharges 17 pounds of sulfur dioxide, about 18 pounds of aldehydes (estimated as formaldehyde), 25 to 75 pounds of oxides of nitrogen (estimated as nitrogen dioxide), 200 to 400 pounds of complex organic compounds, and over 3000 pounds of carbon monoxide.

Sulfur dioxide is both an irritant and a poison. It is probably a major contributor to the high incidence of chronic bronchitis in England. There is evidence to indicate that a fairly low level of sulfur dioxide—“a level not infrequently found in air”—is sufficient to produce temporary spasms of

the smooth muscles in the lungs. In "somewhat higher concentrations," the compound produces severe inflammation and peeling of the respiratory membranes. Formaldehyde is a corrosive poison that not only irritates the respiratory membranes but also affects the central nervous system, and nitrogen dioxide is a highly toxic gas that is extremely dangerous even in such relatively low quantities as 100 parts per million.

Several of the organic compounds produced by the combustion of gasoline and diesel oil are carcinogenic. This has been clearly established by Paul Kotin, of the University of California. When tarry material from the exhausts of motor vehicles was painted on laboratory mice, skin tumors appeared in 50 per cent of the animals. The largest amount of carcinogenic substances, according to Kotin's findings, is produced by slow-running and idling engines—that is, under conditions prevalent in areas with congested traffic (see pages 149-50).

A problem that has been largely ignored in the United States is the danger of chronic carbon monoxide poisoning. Until recently, conventional medical opinion held that carbon monoxide (CO) is rapidly removed from the blood stream. Few physicians regarded the enormous output of the gas by motor vehicles as a danger to public health. According to recent reports, however, carbon monoxide may be retained by the body for relatively long periods of time, perhaps as much as several weeks. The problem has aroused a great deal of concern in Europe, where the conviction is growing that chronic carbon monoxide poisoning is a serious hazard of the automobile era. In the United States, Richard Prindle, of the U. S. Public Health Service, emphasizes that "in a community in which carbon monoxide levels exist, 24 hours a day, seven days a week, for the lifetime of an individual, chronic CO poisoning is a distinct possibility." We need only consider the fact that smoking produces a definite level of carbon monoxide in the blood "to realize that coupling this with frequent, although fluctuating exposures to CO in the ambient air . . . might well lead to serious consequences in a large population."

Another problem that cannot be solved without the co-operation of the entire community is water pollution. Water is a traditional medium for the transmission of germs and toxic substances. During the past three generations vigorous efforts on the part of medical and public health officials have enormously reduced the hazard created by water-borne infectious agents, but today old problems of pollution are beginning to recur and new ones to appear, especially in communities that obtain the greater part of their drinking water from rivers. Although Americans tend to make a fetish of cleanliness, an appalling amount of untreated or inadequately treated urban sewage is discharged into river water—water which is often taken up again for public consumption by communities downstream. Added to urban sewage are wastes from chemical factories, slaughterhouses, and metallurgical plants. Although sewage and industrial wastes have produced local public health crises in the past, the postwar expansion of cities and metropolitan areas is turning water pollution into a grave national problem, comparable in many respects to that created by urban air pollution.

Attempts by federal, state, and municipal authorities to control the contamination of our water are complicated by frequent changes in the composition of industrial and urban wastes. Today drinking water may contain a wide variety of new bleaches, detergents, petrochemical and metallurgical wastes, insecticides, dyes, and radioactive compounds. Few if any of these contaminants are removed by ordinary methods of water purification. Rolf Eliassen, of the Massachusetts Institute of Technology, points out that the "exotic organic chemicals" discharged by petrochemical plants into streams "are not even detected by present conventional means of water analysis." Neither industry nor pollution-control laboratories have been able to form a reliable picture of

the long-range effects of the newer pollutants on public health. "Let us all be honest with ourselves," declares Robert A. Kehoe. "Specifications for human health and welfare, in relation to the common contaminants of many of our sources of water, do not exist, and we shall not be able to deal effectively with this problem of public health until they can be formulated on sound physiological facts."

At the same time, the traditional problem of waterborne infections is gaining greater significance. Many cases of acute illness are being attributed to polluted drinking water. To cite a few examples: In 1957 the number of cases of infectious hepatitis began to increase markedly in Nebraska. The disease, an acute inflammation of the liver, was found predominantly in the eastern part of the state. The outbreaks occurred primarily in urban communities that obtain their drinking water from the highly polluted Missouri River. Although most public health officials tend to be extremely cautious in their comments, Nebraskan authorities made no attempt to conceal their suspicion that the increase in hepatitis cases was due to drinking water contaminated by sewage from upstream communities. Similar explanations have been given for polio epidemics in Salt Lake City and in Edmonton, capital of the Canadian province of Alberta. (Much of the evidence pointing to polluted water as the cause of these outbreaks is circumstantial, but there is no longer any doubt that hepatitis can be communicated by water as well as by personal contact. The Edmonton outbreak suggests that poliomyelitis can also be transmitted by water. Edmonton obtains its drinking water from the Saskatchewan River and the epidemic could be related to a failure of the sewage system at a town upstream.) Both diseases are caused by viruses that are found in human feces and sewage.

True, water-borne diseases and, in some communities, urban air pollution have been more serious in the past than they are today. In 1832, Asiatic cholera spread from Quebec to New York City, where it claimed thousands of lives. Cholera persisted in the city for decades before it was eradicated. Typhoid fever, another waterborne disease, was found everywhere during the last century. Owing to improved methods of public sanitation, the incidence of the disease is now negligible. Similarly, many of the worst pockets of urban air pollution are being "cleared up," to the extent of eliminating some of the dense soot and smoke. The cloud of industrial soot that began to descend on Pittsburgh as early as the 1860's has been lifted. Although Pittsburgh does not enjoy pure air, a reduction has been achieved in the more offensive pollutants that once filled the city's atmosphere. Air pollution programs have gained ground primarily against the smoke and grime of the old Industrial Revolution, just as social reform has scored its greatest triumphs over illiteracy and child labor.

Since World War II, however, there has been a new industrial revolution, and the problems of urban life have acquired new dimensions. On the one hand, the sources of urban pollution have increased in number and variety; many pollutants, such as those produced by the automobile, are difficult to manage, even where everyone is willing to co-operate on the problem. On the other hand, metropolitan regions are being burdened beyond their capacity to cope with air pollutants and to meet the need for clean water. Their waterways and atmosphere are expected to absorb a staggering quantity of waste products from industrial plants, homes, and vehicles. Currently the United States must dispose of over 18 billion pounds of sewage solids every year, an increase of 70 per cent in the past two decades. The water table in many areas of the United States is being lowered by the voracious demands of highly concentrated populations and expanding industries. At the same time that the number of pollutants has increased, the ecological preconditions for wholesome air and plentiful water are being undermined. A major disequilib-

rium is arising between town and country, industry and the biotic environment, and population and regional resources.

Rene Dubos, of the Rockefeller Institute for Medical Research, places smog among the major environmental factors that have unleashed the "Apocalyptic horsemen" of modern disease. According to Dubos, St. John the Divine's vision on the isle of Patmos is symbolic of present-day urban and industrial life. The first horsemen of the Apocalypse to be seen by the saint were Famine and Pestilence. "Then another, even more terrifying visitation was sent by the angered Deity," Dubos recalls. "After the fifth angel had sounded his trumpet he opened the bottomless pit and 'there arose a smoke out of the pit, as the smoke of a great furnace; and the sun and the air were darkened by reason of the smoke of the pit.' And out of the bottomless pit came the scorpions that did not kill men but tormented them for five months before final destruction came 'by the fire, and by the smoke and by the brimstone.' The time of fulfillment of the Apocalypse may not be far off."

Dubos is not being overly dramatic. We are producing a new spectrum of environmental hazards whose full effects still await the passage of time. The trends are not encouraging. "Many diseases that are thought to be associated with, or caused by, air pollution have been increasing over the years," Prindle writes. "Included among these are the respiratory cancers, emphysema, chronic bronchitis, and cor pulmonale. (Emphysema is a pulmonary disorder that often leads to cor pulmonale, a common form of heart disease. Emphysema has become a major disease in London, ranking third (following heart diseases and cancer) as a cause of death among middle-aged males. The increase in emphysema cases, both in London and Los Angeles, is attributed by many medical authorities to air pollution.) If air pollution continues to increase, one can only conjecture that this rising incidence of disease will continue and that the effect upon the health of the nation-and over the technologically-expanding world-may be severely augmented. The overall effect of air pollution on the economy, the health, and the welfare of the people may become a disaster."

The effects of air pollution on public health will be difficult to judge for many years to come. A large number of adults straddle two worlds. They were born and raised in communities that have only recently acquired the features of metropolitan life. The early years of their lives were spent in the pre-nuclear age. But it is difficult to ignore the portents found in the high incidence of chronic diseases in all age groups of the population. Without a basic solution to the problems of urban life, Dubos's apprehension may Dubos's apprehension may prove to be amply justified.

# CHAPTER FOUR: THE PROBLEM OF CHEMICALS IN FOOD

## The Consumer and Commercial Foods

With the rise of an urbanized society, the production of food becomes a complex industrial operation. In contrast with earlier times, when very few changes were made in the appearance or the constituents of food, much of the food consumed in the United States is highly processed. Allen B. Paul, of the Brookings Institution, and Lorenzo B. Mann, of the Farmer Cooperative Service, have summed up the change as follows: "Our grandparents used for baking about four-fifths of the flour milled in this country. They churned almost all the butter Americans ate. They killed and prepared much of the meat eaten. They made their own soups, sausage, salad dressing, clothing and countless other items. Such tasks, which a generation ago were part of farm and home life, have been taken over by commercial factories, 85,000 of them." Of the 85,000 factories cited by Paul and Mann, nearly half were food-processing plants.

It is hardly necessary to emphasize the fact that advances in food technology and methods of transportation have given us many advantages. A large number of seasonal fruits and vegetables are now available throughout the year in canned and frozen form. Foods are generally cleaner than they were a half century ago. Processed foods have enormously reduced the homemaker's burden. Many vegetables, fruits, and meats are shredded, eviscerated, mixed, creamed, cooked, baked, or fried before they reach the kitchen. The homemaker often needs little more than a can opener, a few utensils, and a stove to serve meals that required elaborate preparation and hours of work a generation or two ago.

But the shift from home-prepared to processed foods has not been an absolute gain. Although very little was known about human nutrition a few generations ago, our forebears could make use of what knowledge they had in growing and preparing their own foods. Today the situation is different. A great deal has been learned about the nutrients required for human health, but the cultivation, storage, refining, and, in large part, the preparation of food is no longer controlled by the consumer. These tasks have been taken over by the food industry. In the absence of a nation-wide food-grading program that would compel processors to disclose the nutritive values of food items, the housewife's attempt to plan a healthful diet depends to a great extent upon chance. The nutritive quality of a given food may vary enormously. The variation may be due to the type of seed that the farmer plants, the methods employed in food cultivation and food processing, or the length of time the food is stored.

For example: Nutritionists, in analyzing thirty-one strains of cabbage, found that the ascorbic-acid, or vitamin-C, content varied as much as 350 per cent, while the amount of carotene in different varieties of sweet potatoes has been found to range from zero to 7.2 milligrams per cent. A threefold difference was discovered in the niacin content of forty-six strains of sweet corn. Large variations in nutritive value have been found among different varieties of apples,



peas, wheat, onions, and many other crops. The fact that a given variety attains great size does not necessarily mean that it is nutritious. The very opposite may be true. Small cabbages, tomatoes, and onions, for example, contain more vitamin C than those of greater size. Size, appearance, color, and texture are often very poor criteria for judging the nutritive content of a food. Generally, plant breeders are interested in developing varieties of vegetables and fruits that have an attractive appearance, yield more bushels to the acre, are more resistant to disease, and withstand storage and shipment. "It is now realized that in the development of these commercially improved varieties by genetic selection the nutrient content is often decreased," notes Robert S. Harris, of the Massachusetts Institute of Technology. "If the plant breeder were to collaborate with a food analysis laboratory, he could develop commercially improved varieties which are also superior in nutrient content." (It is quite doubtful, however, whether improvements in the nutritive quality of vegetables and fruits depend exclusively on genetic selection (as Harris seems to believe). The plant environment, notably the condition and fertility of the soil, is a factor of decisive importance.)

Foods may lose much of their nutritive value when they are heated (blanched) prior to canning or freezing. If the processor follows a good blanching procedure, vegetables will retain most of their ascorbic acid and vitamin B. But if the procedure is poor, the losses may be enormous. Losses may run as high as 30 per cent of the riboflavin in green beans, 37 per cent of the niacin in spinach, 40 per cent of the ascorbic acid in peas, and 64 per cent of the thiamine in lima beans. "Blanching procedures are not standardized," Mildred M. Boggs and Clyde L. Rasmussen observe. "Some processors have a leaching loss of 5 to 10 per cent of each water-soluble vitamin or other constituents. Others have losses of 40 to 50 per cent - or even higher with the same food."

A substantial loss of nutrients takes place when wheat is refined into flour for white bread. "Even with 4 per cent milk solids in the white enriched bread," Bogert notes, "it is still not quite up to the content of whole wheat bread in protein, calcium, iron, thiamine and niacin, while the whole grain breads contain other B complex vitamins not added in the enrichment of white flour." If a product is stored too long, it may lose a substantial amount of thiamine. "Pork luncheon," for example, may lose 20 per cent of its thiamine in the can while standing on the retailer's shelf for three months. After six months the loss may be as high as 30 per cent.

Many of these problems could be solved by establishing a compulsory system of grade labeling for processed foods based on their nutritive constituents. The grade markings that currently appear on labels are often meaningless from a nutritional point of view. For the most part, they indicate the food's size, appearance, and taste, not its nutritive value. But the food industry has been adamantly opposed to any kind of compulsory grade labeling. Jesse V. Coles, professor of home economics at the University of California, observes that "practically all, if not all, manufacturers, processors, and distributors are opposed to compulsory grade labeling." In the thirties the food industry defeated attempts to provide for grade labeling in the N.R.A. fair competition codes; it was bitterly opposed to the inclusion of standards of food quality in the food and drug legislation enacted by Congress in 1938; and it successfully blocked efforts to link price regulations with food quality in wartime anti-inflationary laws.

In the absence of a meaningful system of grade labeling, the homemaker is surrounded by nutritional anarchy. Her choice of a product is often governed by its appearance; if it is packaged, she is likely to choose a well-advertised brand or one that is attractively wrapped. Her difficulties are complicated by the fact that many processors color the food she sees and use chemicals to soften the refined products she touches. Preservatives are often added to foods to permit longer

storage, and synthetic flavoring matter is put into many processed foods to enhance their taste. And even in those cases in which appearance, taste, and softness are true indications of superior nutritional quality, the processor frequently uses a large variety of chemicals to make an inferior, stale, or overly refined product seem high in quality.

Aside from the deception they practice on the consumer, many of the chemicals added to foods are known to be active toxicants. Presumably they are "safe under the conditions of their intended use," to borrow a phrase formulated by the Food and Drug Administration, but the word "safe" does not mean that the chemicals do no damage. In view of the fact that they are harmful even in relatively small quantities, it is likely that toxicants in foods inflict a certain amount of damage on nearly all animal organisms, including man. Another group of food additives is enveloped in an air of biochemical mystery; very little is known about how they react during animal metabolism. Many additives are chemically unique or "exotic." Until they were developed by chemists, the compounds never appeared in foods, and their long-range effects on the human body have yet to be determined.

The overwhelming majority of people in the United States derive their nourishment from commercial foods. If a harmful chemical finds its way into a popular food, many individuals are likely to be affected. These individuals differ in age, state of health, genetic endowment, environmental background, and susceptibility to the toxicity of the chemical. Some individuals may be more vulnerable to the toxicant than others, although they may never show any symptoms of acute illness. (There have been cases, however, in which hundreds and even thousands of people suffered acute disorders caused by chemical additives in commercial foods. According to newspaper accounts, as recently as 1960 nearly 100,000 people in the Netherlands were poisoned by a chemical emulsifier that had been added to a popular margarine. The margarine was manufactured by one of the most reputable food processors in Europe. The emulsifier produced an eczema-like rash on many parts of the body and temperatures as high as 106 degrees. At least two deaths were attributed to the emulsifier. About 5 million packages of margarine had been distributed to retailers before the effects of the additive were discovered.) The research devoted to chemicals in foods seldom goes beyond the effects they produce in laboratory animals. A chemical additive is tested on rats and dogs for about two years. If the chemical causes no apparent damage to tissues and organs, it may be used in food. If it is obviously toxic "under the conditions of its intended use," it will be rejected. But laboratory animals are not men. Their physiology is different from that of human beings and they are unable to communicate important reactions that may well escape the notice of the researcher. Although experiments on rats, dogs, and even monkeys are useful in forewarning man against harmful substances, they do not supply conclusive evidence that chemicals which cause no apparent damage to animals are harmless to man.

Evidence that a chemical is harmful may well appear years after it has been permitted in foods. The use of additives regarded as safe only a decade or two ago has been forbidden because later, more exacting studies showed that these chemicals have toxic properties. According to Consumer Reports, coal-tar dyes were certified by the Food and Drug Administration for use as food colors "on the basis of hasty, old-fashioned, and otherwise inadequate testing, and recent advances in research methodology have led to the conclusion that the safety of most of them is unknown. Since 1945, when the FDA began to apply modern methods of study and research to certifiable dyes, 15 food dyes have been reexamined for toxic, carcinogenic or allergenic properties. Only one of these, Yellow No. 5 (used to color candies, icings, and pie-fillings, for example) has been conclusively shown to be harmless. Last year [1955], Orange No. 1, Orange No. 2, and Red No.

32 were decertified as too toxic for use in foods. The FDA announcement said that 'while manufacturers will no longer label and sell these three colors for use, they may label and sell them for external drug and cosmetic use.' Orange No. 1 had been widely used in candy, cakes, cookies, carbonated beverages, desserts, and such meat products as frankfurters. Orange No. 2 and Red No. 32 were used to color the outer skin of oranges, and during the Christmas season last year, some 150 children were made ill in California as a result of eating popcorn colored with Red No. 32."

Whether a food additive is classified as harmful or not depends not only upon laboratory techniques but on the standards of the researcher. Every investigator is confronted with the following questions: How thoroughly should the chemical be studied? On how many species? What constitutes reasonable evidence that a chemical additive is harmless to man? In hearings before the Delaney Committee more than a decade ago, many conflicting answers were given to these questions. Some eminent researchers advanced the view that tests should be conducted through the whole life span of many animal species, while others seemed to be satisfied with limited experiments on rats. The generally accepted criteria for evaluating the toxicity of food additives represent an unstable compromise between widely divergent scientific views and are subject to serious challenge.

While disputes over the adequacy of current testing standards continue, the problem of chemical additives in food becomes greater with every passing year. Chemicals are used in nearly every phase of the production, storage, and merchandizing of food. It is difficult to find a single commercial food that has not been exposed to a chemical compound at some stage of cultivation or processing. Many foods accumulate a large number of residues and additives as they travel from the farm through the processing plant to the retail outlet. Grain, for example, is dusted repeatedly with insecticides and fungicides and then treated with fumigants during storage. At the processing stage, chemicals are added to facilitate handling and to improve the consistency of the flour. The flour is bleached and treated with preservatives. The final product may be colored and wrapped in chemically treated paper that sometimes transfers undesirable substances to the food. Are all of these chemicals indispensable to an ample supply of food? Do any of them constitute hazards to public health? At a time when the number of chemicals in our food is reaching staggering proportions, these questions require considered replies.

## Chemicals in Agriculture

The claim is often that without chemicals to protect our orchards and fields from pests, we could not possibly have a modern, productive system of agriculture. "There is abundant evidence that our fruit, vegetables and many other staple crops cannot be produced economically, efficiently, and in an adequate volume without chemical protection from insects, plant diseases, weeds, and other pests," observes George C. Decker, a noted American entomologist. "To deny agriculture the use of these chemical tools would be to jeopardize our agricultural economy and an adequate, well-balanced food supply for the American public. Uninhibited insects and plant diseases would largely eliminate the commercial production of such crops as apples, peaches, citrus fruits, tomatoes, and potatoes, to mention only a few, and would drastically curtail the production of many other major crops."

Although no one would want to jeopardize our agricultural economy, still less deny the American people a well-balanced diet, a great deal of public and professional concern has been aroused by the presence of pesticidal residues in food. An insecticide should be "used as a stiletto rather than a scythe," A. W. A. Brown writes. "Ideally it should be employed to punch a particular hole in the food chain, which, if it cannot be filled in by [other species in the] neighboring elements of the biota, at least should be done at such a time of season that it does not seriously disturb the biota." In practice, the trend has gone in the opposite direction. Insecticides are not only becoming more lethal; they are being used with less and less discrimination. Aside from the ecological implications of this trend, the growing toxicity and variety of insecticidal residues in food have become one of the major health problems of our time.

The large-scale application of insecticides to field crops did not get under way until the 1860's, when a large number of American farmers began to use Paris green (copper acetoarsenite) against the Colorado potato beetle. The effectiveness of this insecticide encouraged chemists to develop a variety of other formulas. Most of the new insecticides were inorganic compounds - preparations of arsenic, mercury, and sulfur - which normally remained on the crop after harvesting. The residues ranged in amount from mere traces to quantities large enough to be hazardous to the consumer. As early as 1919 the Boston Board of Health condemned shipments of western pears because of excessive arsenic residue, and six years later British health authorities raised strong objections to the amount of arsenic found on imported American apples. Finally, federal officials placed limits on the amount of arsenic that could be allowed to remain on commercial apples and pears. Ironically, for a brief period the original limits, or tolerances, for food sold to domestic consumers were two and a half times higher than those established for apples exported to Europe.

Although the prewar era of inorganic insecticides has been described as pristine in comparison with the present era of organic preparations, the situation was far from ideal. In the 1930's one of the most widely used inorganic compounds, lead arsenate, combined a suspected carcinogen (arsenic) with a cumulative poison (lead). Calcium arsenate seriously damaged the soil, especially soils low in hummus. Many areas of Washington and South Carolina were rendered unproductive as a result of being dusted with large amounts of arsenicals. Harmful as they are, however, prior to 1945 inorganic insecticides were employed in relatively modest quantities and in a limited variety. The most lethal preparations were used primarily for agricultural purposes, and the greater part of the residue could be removed from the surface of the crops by careful washing.

After World War II, the insecticide problem acquired entirely new dimensions. The total quantity of insecticides used prior to the war was but a fraction of the amount employed in the mid-1950's. Annual domestic sales of pesticides (primarily insecticides) increased more than sevenfold between 1940 and 1956. Inorganic insecticides, though still in use, declined markedly in importance; they were supplanted for the most part by a whole new group of organic preparations. Of these the best known is DDT, a chlorinated hydrocarbon; it was synthesized as early as 1874, but it remained a little-known chemical compound until the late 1930's, when the Swiss chemist Paul Muller discovered its insecticidal properties. The American armed forces began using it in 1943, a year after the first small quantities had been shipped to the United States for experimental purposes. While the war was still in progress, A. P. Dupire in France and F. J. Thomas in England began to work with benzene hexachloride (BHC), another chlorinated hydrocarbon that had been synthesized in the last century. The research of Thomas and his colleagues led to the discovery of the insecticidal properties of lindane, a form of BHC. Significant work was also being done in Germany during this period. Shortly before the war, Gerhard Schrader, while engaged in re-

search on poison gases, discovered a series of extremely lethal organic phosphates, from which parathion, malathion, and other now familiar preparations were developed. The list continued to grow until an impressive number of chlorinated hydrocarbons and organic phosphates were available for use on farms and in gardens, warehouses, stores, and homes.

In retrospect, the carelessness with which some of these insecticides were delivered to the public is incredible. The chemical behavior of the chlorinated hydrocarbons inside the human body is still unknown, although it has been determined that both the chlorinated hydrocarbons and the organic phosphates are powerful nerve toxicants. The organic phosphates are known to inactivate the enzyme cholinesterase, which participates in the chemical control of nerve impulses. (Until recently, virtually nothing was known about the effects of extended exposure to low doses of organic phosphates, and it was generally assumed that there were no long-term effects at all. In June 1961, however, S. Gershon and F. H. Shaw, of the University of Melbourne, reported that schizophrenic and depressive reactions, with severe impairment of memory and difficulty in concentrating, were found in sixteen individuals who had been exposed to organic phosphates for one and a half to ten years.) Solutions of organic insecticides are absorbed through the skin as well as the lungs and digestive tract. The skin does not offer an effective barrier to the entry of these toxicants when they are used in liquid form. The younger an organism, the more easily it is poisoned. Both groups of insecticides produce effects in warmblooded animals very similar to those they produce in insects. Farm animals poisoned by DDT and other chlorinated hydrocarbons first become restless and excitable; the next stage is characterized by twitching, spasms, and, finally, convulsions. Animals poisoned by the organic phosphates usually die of respiratory failure, but in these cases, too, convulsions have been known to occur.

Fortunately, DDT, the first of the new organic insecticides to be widely used, is one of the milder chlorinated hydrocarbons. The compound began to reach American farms in 1945. As test samples of DDT had arrived in the United States only three years earlier, American research on the compound up to that time had been necessarily limited. Some of its more disquieting features were still under study when many Americans began using it with reckless abandon as a "magic bullet" against insect pests. At this stage, very little was known about the way the human body reacts to DDT, the possibility of chronic toxicity, the existence of the indirect routes by which DDT enters the human body, and DDT's stability under varying agricultural conditions. By 1950, when a number of these questions had been answered, it had become evident that although the insecticide is certainly a "magic bullet," the target toward which it is traveling is very much in doubt.

It was found that DDT tends to concentrate heavily in fat. A relatively low dietary intake of the insecticide is magnified from six to twenty-eight times in the fat deposits of the body. According to A. J. Lehman, of the F.D.A., the continual ingestion of as little as 5 parts per million (ppm) of DDT in the diet produces "definite though minimal liver damage" in rats. Such an intake is not likely to be uncommon in the United States. The F.D.A. has placed a residue tolerance of 7 parts per million of DDT on nearly every fruit, vegetable, and portion of animal fat that reaches the American dinner table. But the agency does not know how many farmers are honoring these tolerances. As recently as December 1959, F.D.A. Commissioner George P. Larrick confessed that economic incentives to use chemicals in agriculture are so compelling that his organization "can hardly be expected to control the problem adequately."

The reputation of DDT suffered its first blow only two years after the end of the war. As early as 1947, Italian entomologists noted that DDT-resistant flies were appearing in many parts of

Italy. Similar reports began to come from California and other areas in the United States. By 1950, American surveys had shown that previously susceptible strains of flies "were becoming resistant to DDT over a period of 2 or 3 years." Entomologists and public health workers were still hopeful that the malaria-carrying mosquito would continue to succumb to DDT, but this insect also developed DDT-resistant strains. As the number of resistant insects began to multiply, attention shifted to more lethal preparations, such as chlordane, dieldrin, and the organic phosphates.

Chlordane and the dieldrin-aldrin group of preparations are highly toxic chlorinated hydrocarbons. A portion of the testimony and data that the Delaney Committee received on chlordane is summarized in its report as follows: "The Director of the Division of Pharmacology of the Food and Drug Administration [A. J. Lehman] testified that from a chronic viewpoint chlordane is four to five times more toxic than DDT, and that he would hesitate to eat food that had any [chlordane] residue on it whatever. He stated that chlordane has no place in the food industry where even the remotest opportunity for contamination exists, and that it should not be used even as a household spray or in floor waxes." Later experimental work showed that chlordane, when fed to rats, has about twice the chronic toxicity of DDT; the insecticide produces detectable liver damage when ingested in amounts as low as 2 1/2 parts per million.

Dieldrin and aldrin, according to Lehman, create a danger of chronic toxicity that "may be similar" to that posed by chlordane. These insecticides have the "rather rare property of being more toxic by skin absorption than by oral ingestion, the ratio being about 10:1. To state this another way, dieldrin and aldrin are approximately 10 times more poisonous when applied to the skin than when swallowed... Neither of these compounds is irritating to the skin in low concentrations so that the individual has no warning of skin contact."

The F.D.A. permits residues of chlordane, dieldrin, and aldrin on nearly all the vegetables and fruits sold to American consumers. In view of current spraying practices, it is not unusual for foods to accumulate residues of several chlorinated hydrocarbons. The fact that the various insecticides have different chemical properties is small reason for comfort. "Studies in our laboratories have shown that when low concentrations of several insecticides are fed to rats the effect is additive," Lehman writes. "For example, when 2 ppm each of DDT, chlordane, lindane, toxaphene, and methoxychlor, making a total of 10 ppm of chlorinated hydrocarbons, are added to the diet of rats, liver damage results. With the possible exception of chlordane, none of the insecticides listed, when fed individually at 2 ppm, would injure the liver, but in their combination their effect is additive."

Where do we stand today in our chemical war against the insect world? Although partial control has been achieved over some carriers of disease, and other pests are no longer the nuisance they once were, the basic problems of insect infestation remain unsolved. Herbert F. Schoof observes that "man's insect enemies are adapting to successful coexistence with pesticides almost as rapidly as new technics and toxicants are produced." We are paying a heavy price for our questionable gains against agricultural pests. A larger quantity of insecticides is required almost every year. The production of DDT in the United States nearly doubled between 1950, when the compound was no longer a novelty, and 1958. Nearly 100 million pounds of aldrin, chlordane, dieldrin, endrin, heptachlor, and toxaphene-chemicals virtually unknown to farmers in the 1940's - were produced in 1958. Approximately 3 billion pounds of pesticides, including herbicides, fungicides, and fumigants, are produced annually in the United States. "The pesticide industry is growing by leaps and bounds and entomologists predict, and chemical manufacturers hope for, a fourfold

expansion in use of pesticides during the next ten to fifteen years," observes Clarence Cottam, of the Welder Wildlife Foundation. "Today, well over 12,500 brandname formulations and more than 200 basic control compounds are on the market. Most of the currently used pesticides were unknown even ten years ago. Furthermore, and contrary to the public interest, most new pesticides are decidedly more toxic, generally more stable, and less specific in effect than those of but a few years back."

The postwar era also witnessed the introduction of highly potent chemical agents for increasing the weight of livestock. In 1947 the F.D.A. approved the use of stilbestrol pellets for "tenderizing" the meat of poultry. Stilbestrol, a synthetically prepared drug, causes bodily changes that are identical with those produced by certain female sex hormones (estrogens). The drug was approved for use with the understanding that poultrymen would implant a single pellet in the upper region of the chicken's neck about a month or two before marketing. Presumably this period was sufficient for the complete absorption of the chemical, so that no residues would be left in the flesh of the bird. Male birds treated with stilbestrol undergo radical physiological changes; their reproductive organs, combs, and wattles shrivel, and they lose all inclination to crow or fight. The drug tends to cause substantial increases in weight in both sexes, producing plump birds with skin that is noticeably smooth in texture.

Careful investigation has shown that stilbestrol increases the over-all fat content of chickens by 40 percent. In the hearings before the Delaney Committee, Robert K. Enders, professor of zoology at Swarthmore College, expressed his agreement "with those endocrinologists who say that the use of the drug to fatten poultry is an economic fraud. Chicken feed is not saved; it is merely turned into fat instead of protein. Fat is abundant in the American diet so more is undesirable. Protein is what one wants from poultry. By their own admission it is the improvement in appearance and increase in fat that makes it more profitable to the poultryman to use the drug. This fat is of very doubtful value and is in no way the dietary equal of the protein that the consumer thinks he is paying for."

By the late 1950's approximately 100 million hormone-treated fowl were being marketed annually to American consumers. In a number of limited surveys, the F.D.A. found that stilbestrol pellets often remained in the necks of poultry until after the birds had reached wholesale outlets; the pellets were not completely absorbed, stilbestrol was detected in the edible tissues of hormone-treated fowl even after the heads and necks had been removed. Finally, in December 1959, the F.D.A. announced that, on its recommendation, the poultry industry had agreed to discontinue the use of the synthetic estrogen. It is doubtful whether either the F.D.A. or the poultry industry had very much choice. Stilbestrol is suspected of being a cancer-promoting drug, and recent federal legislation specifically prohibits the presence of carcinogenic additives in food. Pellets of stilbestrol are still implanted in the ears of cattle, however, and the drug is widely used as a supplement to the feed of steers and sheep. The official opinion today is that no residues of the drug will remain in large animals if breeders obey F.D.A. regulations, but the evidence to support this opinion is open to question (see pages 140-1).

The use of synthetic estrogens in livestock management was soon followed by the addition of antibiotics to feed, a technique that dramatically accelerates the growth of domestic animals. Although there is no evidence that antibiotics affect the nutritive quality of meat, research conducted by the F.D.A. showed that chlortetracycline and penicillin could be detected in the blood, tissues, and eggs of chickens given feed containing as little as 50 parts per million of the drugs. This quantity does not exceed the limits established by the F.D.A. for antibiotics in feed. Ac-

cording to William A. Randall, of the F.D.A.'s Division of Antibiotics, the "small amounts found in chicken tissue were destroyed following frying. Furthermore, when the antibiotic-containing feed was withdrawn and normal feeding begun the antibiotic disappeared from the tissue or eggs within a few days. After hard-boiling eggs containing antibiotics, no activity could be detected in the great majority of those tested."

But we should place the emphasis where it properly belongs. Antibiotics could be detected even in eggs that were hard-boiled, and residues were found in the tissues and eggs of chickens after normal feeding was restored. Accordingly, current F.D.A. regulations prohibit the use of antibiotics in the feed of egg-laying hens and require that, in the case of poultry destined for human consumption, normal feeding be restored four days prior to slaughtering. "It may well be in the public interest to reserve this valuable class of drugs for the purpose for which they were originally developed," Randall concludes, "that is, the prevention and treatment of disease."

This conclusion is not without merit. Many farmers pay very little attention to the F.D.A.'s regulations, and nearly all farmers ignore them at one time or another. The situation is similar to that faced by the police in trying to keep motorists from speeding; almost everyone occasionally exceeds the speed limit. But in the case of the F.D.A. regulations, the violator's chances of being caught are infinitesimal in comparison with those of the speeder. Although its inspection program is totally inadequate to cope with the problem of chemicals in food, the F.D.A. has already discovered violations of its regulations on feed supplemented with arsenic compounds, another widely used promoter of growth. "A very preliminary survey made some time ago by the Food and Drug Administration indicated that some poultry raisers are not withholding arsenic-containing feeds from their flocks 5 days before slaughter," complained Arthur S. Flemming, former Secretary of Health, Education, and Welfare, "and we have information that in some parts of the country, hog raisers maintain their animals on arsenic-containing feed within the 5-day period that the arsenic is supposed to be withheld. It is evident that such disregard for safe use could lead to added arsenic residues in poultry and pork on the retail market and thus could frustrate the public health safeguards upon which the original approvals were granted."

Antibiotics are dangerous food additives. The sensitivity of many persons to penicillin has reached a point where a therapeutic dose of the drug can be expected to claim their lives. Such individuals are increasing in number with every passing year. Cases have already been reported in which penicillin used to treat infections in dairy cattle entered the milk supply in sufficient quantities to cause severe reactions in human consumers. According to Murray C. Zimmerman, of the University of Southern California, data on milk contamination suggest that a person who drinks two quarts of milk every day "could ingest over 1,000 units of penicillin daily. The fact that penicillin 'naturally' present in milk has not previously been proved to cause allergic reactions is outweighed by the fact that this is almost a billion times more penicillin than has previously been shown necessary to provoke reactions. Coleman and Siegel reported a patient with a reaction on passive transfer to 0.00001 units of penicillin. Bierlein's patient went into shock when skin-tested with 0.000003 units of penicillin." Zimmerman then proceeds to discuss detailed case histories of four patients whose reaction to penicillin could be traced with reasonable certainty to the consumption of dairy products.

It is quite conceivable that the extensive use of antibiotics in agriculture will slowly turn our domestic animals into a major reservoir of antibiotic-resistant bacteria. This represents a problem fraught with incalculable dangers to public health. Feed supplemented with tetracycline, for example, has already produced resistant strains of *Bacterium coli* and *Clostridium perfringens*.



Both bacteria typically inhabit man's alimentary tract, but under certain circumstances they behave as disease-causing organisms. "Examination of pigs and poultry kept on many different farms showed that the B. cold in the feces of tetracycline-fed animals were predominantly tetracycline-resistant," observes H. William Smith, of the Animal Health Trust in Sussex, England, "while those in the feces of animals on farms where tetracycline feeding was not practiced were predominantly tetracycline-sensitive. In some herds in which tetracycline feeding was just being introduced it was possible to trace the changes of the B. cold fecal flora from tetracycline-sensitive to tetracycline-resistant." Smith notes that similar changes could be traced in the case of *Clostridium perfringens*.

The use of shotgun methods to treat or forestall udder infections in cattle with penicillin has almost certainly increased the propagation of resistant strains of *Staphylococcus aureus*, the principal culprit in the common "staph infection" and the direct cause of grave, often fatal cases of pneumonia. Smith notes that the proportion of penicillin-resistant *Staphylococcus aureus* cultures isolated from herd samples of milk in Britain "had increased from 11 % in 1954 to 47 % in 1956." Two bacteriologists of the Canadian Food and Drug Directorate, F. S. Thatcher and W. Simon, in analyzing cheese that had been purchased in retail outlets, found substantially more penicillin-resistant staphylococci "than would be expected in a normal population not exposed to antibiotic therapy... With regard to the streptococci recovered from cheese our results show a close approximation to the degree of resistance to penicillin found among comparable species isolated from hospital patients."

Thatcher and Simon conclude their report with the warning that "where penicillin or other antibiotics are used with dairy cattle, the survival of resistant organisms may lead to widespread distribution of resistant strains into the homes of the general populace, since staphylococci and streptococci, often in large numbers, are of common occurrence in cheese. Foods so contaminated may well contribute to the severity of the problem arising from infections in man with resistant strains without the patients having received prior antibiotic therapy or without having been exposed to endemic infections within hospitals."

But in the United States this is no longer merely a potential hazard. Already there have been two localized epidemics of "staph infections" that have been attributed to contact with cattle. During 1956 and 1957 about 36 per cent of the senior students and 26 per cent of the faculty at the Veterinary School of the University of Pennsylvania contracted "staph infections." In 1958 another epidemic of the infections occurred among 44 per cent of the senior students at the Colorado State University College of Veterinary Medicine. There is good reason to believe that, in both cases, animals handled by the students had become a reservoir of antibiotic-resistant staphylococci.

The current trends in agriculture reflect a shocking indifference to the long-term health of our population. By recklessly overcommitting ourselves to the use of chemicals in the growing of our food, we have turned highly potent toxicants and drugs, which we would be justified in using only on a limited scale or in exceptional circumstances, into the foundations of our agriculture. These foundations are extremely unstable and the edifice we are trying to construct may prove to be a trap rather than a habitable dwelling. Insecticides commonly aggravate the very problems they are meant to solve. The ecological difficulties they create lead to the use of increasingly toxic preparations, until a point is reached where the insecticides threaten to become more dangerous in the long run to the human species than to the insects for which they are intended. The need to rescue a crop from agricultural mismanagement gains priority over the health and wellbeing of

the consumer. The use of drugs to fatten and accelerate the growth of domestic animals is playing havoc with the physiology of our livestock. The damage these drugs inflict on poultry and cattle necessitates the use of additional drugs, which, in turn, contaminate man's food and reduce the value of these agents in combating disease. It would seem to be a form of ecological retribution that the very forces man has summoned against the living world around him are being redirected by a remorseless logic against the human organism itself.

## Chemicals in Food Processing

The same overcommitment to potentially risky methods is found in other phases of food production. Complex problems of storage, cleansing, handling, refining, cooking, mixing, heating, and packaging are often solved by the use of chemical additives. A half century ago the yellowish tint in freshly milled flour was removed slowly by aging; today it is removed rapidly by oxidizing agents. The miller no longer has to store flour and wait for it to mature. Emulsifiers are employed, partly to "improve" the texture of a product, partly to speed up processing. Their "functional advantages" in ice cream, for example, are that the "mix can be whipped faster, the product from the freezer is dryer, and the mix has less tendency to 'churn' in the freezer." Chemical antioxidants are used to help prevent oils and fats from becoming rancid, a problem that becomes especially pronounced when natural antioxidants are removed during large-scale processing. Chemical preservatives are added to food to permit longer storage in wholesale depots and to extend the "shelf life" of a product in retail outlets. In time chemicals are turned from mere adjuncts of food production into "technological necessities." Their use may result in new machines and facilities, the abandonment of old processing methods, and a broad reorientation of technology to meet the new chemical requirements.

The fact that a chemical is technologically useful does not mean that it is biologically desirable. The two phrases are occasionally used interchangeably, as though they were synonymous. Some of the chemicals most widely used in the production of food have been found to be harmful to animals in laboratory tests. Nitrogen trichloride, or agene, was employed for decades as a bleaching and maturing agent in flour before it was discovered, in 1946, that the compound produces "running fits," or hysteria, in dogs. The use of agene in the bread industry has since been discontinued. Although there is no evidence that agenized flour causes nerve disorders in man, no one can say with certainty that cereal products treated with agene are completely harmless to consumers, especially if eaten day after day for twenty years or more. The toxicant in agenized flour "produces nervous disturbances in monkeys, but not epilepsy in man," observed the late Anton Carlson, one of the most distinguished physiologists of his day. "That is not sufficient for me, because there are many other types of nervous disturbances... that may be aggravated or introduced by this chemical."

Another group of chemicals, notably certain types of polyoxyethylene derivatives, were widely used in the United States as emulsifiers before they were banned as potential hazards to consumers. Former F.D.A. Commissioner Charles W. Crawford is reported to have described the agents as "good paint removers." According to data furnished to the Delaney Committee, rats that had been fed two commercial preparations of polyoxyethylenederived emulsifiers showed blood in their feces and developed a variety of kidney, abdominal, cardiac, and liver abnormalities. These preparations were used primarily as bread softeners but also found their way into

other foods. The polyoxyethylene derivatives constitute a highly suspect family of emulsifying agents, yet some of them are still added to cake mixes, cake icing, frozen desserts, ice cream, candies, dill pickles, fruit and vegetable coatings, vitamin preparations, and many food-packaging materials. (Several experiments indicate that an intake of large amounts of polyoxyethylene (8) stearate produces gall stones and bladder tumors in rats. At least two commercial preparations of polyoxyethylene derivatives are reported to be co-carcinogens; they promote the development of skin cancer in mice when used in conjunction with certain carcinogenic agents. For a number of years all three of these polyoxyethylene compounds were used as food additives in the United States. By the early 1950's, polyoxyethylene derivatives had also migrated to England, where they were used on a limited scale as bread softeners.)

Similar examples can be culled from other groups of chemical aids. In general, the toxic effects of many commonly used compounds are difficult to determine, but individually and in groups they have aroused suspicion and concern. "The fortification of oils and fats against oxidation and rancidity is another field in which there are serious questions of possible toxicity," warns F. J. Schlink, technical director of Consumers' Research and editor of *Consumer Bulletin*. "The natural antioxidants which delay rancidity are lost during the factory processing of refined oils and fats; then the attempt is made to restore the antioxidation qualities by addition of fat-stabilizing substances. Most of the materials that have antioxidation properties are known to be toxic to some degree."

The term "technological aid" has been used loosely to include food additives that could be dispensed with entirely if a manufacturer improved his processing methods and the quality of his product. The question of whether a chemical, instead of being legitimately employed to furnish distant consumers with a perishable product, was being used rather as a device for masking inferior ingredients and unsanitary methods arose in sharp form early in the century, when sodium benzoate was employed extensively as a preservative in ketchup. Harvey Wiley, the first administrator of the federal food and drug law, regarded sodium benzoate as a hazard to consumers. Supported by data from feeding experiments performed with human beings, Wiley claimed that the preservative causes injury to the digestive system. He was convinced that ketchup need not deteriorate readily if clean facilities and proper ingredients are used in preparing it. Challenged on this point by Charles F. Loudon, a canner in Terre Haute, Indiana, Wiley appointed a bacteriologist, Arvill W. Bitting, to work at the Loudon factory and prepare a formula for a stable ketchup preparation without artificial preservatives. Bitting was successful. Moreover, after inspecting numerous canning factories and examining many brands of ketchup, Bitting concluded that manufacturers who needed sodium benzoate often used inferior products and were careless about sanitation.

"The whole spirit and tradition of the pure-food law is against the use of preservatives and substitutes," declared Mrs. Harvey Wiley more than forty years after the Loudon episode. "The intent of the law is to encourage the manufacture of high-grade ingredients, not to try to hide inferiority and cheapness by the use of chemicals and preservatives." If this is so, the spirit of the law has been ignored for decades. The most up-to-date surveys of chemical additives in foods show that preservatives are added to cheese, margarine, cereal products, jams, jelly, and many other processed foods. Uncooked poultry is dipped in solutions of antibiotics. (Notably the tetracyclines. Despite strong pressure from the food industry, the British Food Standards Committee has refused to recommend the use of tetracyclines as preservatives for poultry and fish.) Aside from the

damage to public health that may arise from the use of questionable chemicals as preservatives, the longer "shelf life" acquired by some of these foods may cause a loss of valuable nutrients.

Many chemical additives in foods perform no technological or nutritional function whatever. They cannot be regarded as materially useful by any stretch of the imagination. These chemicals enhance the color of a food or make certain products feel soft and newly prepared; in some instances they have been used to replace costly but valuable nutrients with inferior ones. In the least objectionable cases, an additive will deceive the consumer without impairing his health. The application of an innocuous vegetable dye to some foods often leads the consumer to believe that he is acquiring a better, more wholesome, or tastier product than is actually the case. In the most objectionable cases, a chemical is toxic to a greater or lesser degree. This type of additive not only serves to change the appearance or conceal the nutritive deficiency of a food; it exposes the consumer to a certain amount of damage.

Nitrates and nitrites, for example, are used to impart a pink color to certain brands of processed meat. Ostensibly, this is their sole function. The addition of these chemicals to meat, especially frankfurters and hamburger meat, would be objectionable if only because of the deception which makes it difficult for the housewife to distinguish between high-quality and low-quality products. But this is not the only deception perpetrated on the consumer. Used together with salt, nitrite compounds definitely extend the "shelf life" of processed meat products.

When nitrites are ingested, they react with hemoglobin in the blood to form me/hemoglobin, and, like carbon monoxide, reduce the hemoglobin's capacity to carry oxygen. An individual who consumes three to four ounces of processed meat containing 200 parts per million of sodium nitrite (a permissible residue) ingests enough of the compound to convert from 1.4 to 5.7 per cent of his hemoglobin to me/hemoglobin. Ordinarily, this percentage is insignificant. But if the same individual is a heavy smoker and lives in an air-polluted community, the cumulative loss in oxygen-carrying capacity produced by the nitrites in the food and by the carbon monoxide in tobacco smoke and motorcar exhaust can no longer be dismissed as trivial. Sodium nitrite is highly toxic in relatively small amounts. About four grams of the compound constitutes a lethal dose for adults. Although Lehman regards 200 parts per million of sodium nitrite as a safe residue, he notes that "only a small margin of safety exists between the amount of nitrite that is safe and that which may be dangerous. The margin of safety is even more reduced when the smaller blood volume and the corresponding smaller quantity of hemoglobin in children is taken into account. This has been emphasized in the recent cases of nitrite poisoning in children who consumed weiners and bologna containing nitrite greatly in excess of the 200 ppm permitted by Federal regulations. The application of nitrite to other foods is not to be encouraged."

Emulsifiers have been used in bread not only as softening agents, which can give stale bread the texture of newly baked bread, but as substitutes for nourishing ingredients. "The record of the bread-standards hearings contain evidence of distribution among bakers of advertising material advocating the replacement of fats, oils, eggs, and milk by emulsifiers," George L. Prichard, of the Department of Agriculture, told the Delaney Committee. "The use of such products as components of food may work to the disadvantage of our farm economy by displacing farm products normally used. The record indicates that natural food constituents, such as fats and oils, probably will be reduced in many commercial bakery products if bakers are allowed to employ these emulsifiers."

This substitution affects more than the farm economy, however; it also works to the disadvantage of the consumer. To illustrate this, the Delaney Committee report compared the ingredients

in two cake batters prepared by the same company eleven years apart; during the interval emulsifiers were added to the product. The first batter, made in 1939, did not contain synthetic emulsifiers; the second, prepared in 1949, did. "On a percentage basis, the cake batter in 1939 contained 13 per cent eggs, and 8.6 per cent shortening. In 1949, the cake batter contained 6.3 per cent eggs, and 4.8 per cent shortening, with somewhat less than 0.3 per cent of synthetic emulsifier." The report noted that a "synthetic yellow dye could be added to provide the color formerly obtainable through the use of eggs. The utilization of synthetic yellow dye in commercial cake was practiced before the war. There are indications that the use of artificial coloring matter is increased when quantities of whole eggs or egg yolks are reduced in commercial cake formulas."

To heighten the insult, among the most commonly used emulsifiers in 1949 were the polyoxyethylene monostearates. The yellow dye referred to in the Delaney Committee report was probably FDC Yellow No. 3 (Yellow AB), which, until fairly recently, was added to many yellow cake mixes. As we shall see in the following chapter, the dye often contained impurities of a potent carcinogen and its use in foods was forbidden in 1959. For a number of years, however, both the emulsifier and the dye undoubtedly appeared in many brands of cake and reached large numbers of unsuspecting consumers.

Problems of this kind are not likely to disappear unless there is a basic change in the viewpoint of the F.D.A. "Inherited from the Wiley era is a too common misconception that all 'chemicals' are harmful, and the related idea that any amount of a 'poison' is harmful," the F.D.A. observes in a brochure on food additives. "The fact is, of course, that chemical additives, or food additives as they are now being called, have brought about great improvements in the American food supply. Additives like potassium iodide in salt and vitamins in enriched food products are making an important contribution to the health of our people, and yet it is a fact that both iodine and some of the vitamins would be harmful if consumed in excessive amounts. Many similar examples could be given to refute these common misconceptions."

This argument is grossly misleading. Iodine and vitamins are indispensable to human life, but coal-tar dyes and benzoic acid, for example, are not. If we adhered to a well-balanced diet of properly prepared natural foods, iodine and vitamins would never enter the body in toxic amounts. Coal-tar dyes, on the other hand, are suspected of being harmful to man in nearly any amount if consumed repeatedly, and the kindest statement that can be made for the presence of benzoic acid in food is that the compound is "safe under the conditions of its intended use."

The formula "safe under the conditions of its intended use" exposes the consumer to serious risks when it opens the door to the use of food additives whose biochemical activity is not understood. Many unexpected problems may arise when such additives appear in food. A particular additive may seem to be relatively harmless to the organs of the body, but it may be carcinogenic on the cellular level of life. Another additive may produce insignificant or controllable effects when studied in isolation; brought into combination with various chemicals in food, however, it may give rise to toxic compounds. The body, in turn, may make a toxic additive more poisonous in the course of changing it during metabolism. At one time it was generally believed that whenever a toxic substance was absorbed the body was capable of calling upon special mechanisms for detoxifying the toxicant," Lehman observes. "It was believed also that the metabolic pathway that the toxicant followed always proceeded in the direction of the formation of a less toxic compound. Later work on the metabolism of drugs and toxic substances showed that special mechanisms did not exist, but that the toxicant was subject to the same metabolic influences as those which normally operate in the body. The assumption that the metabolic product was

less poisonous than the parent substance from which it was derived is also unwarranted simply because in many instances the toxicity of either the original substance and its conversion product is unknown. In other instances the metabolic product is even more poisonous than its parent. The conversion product, heptachlorepoxyde, which is two or three times more poisonous than the parent substance, heptachlor [a widely used insecticide], may be cited as an example of this."

Finally, food additives may cause allergic reactions that are likely to go unnoticed for many years. The reactions need not be severe to be harmful. Otto Saphir and his colleagues at the Michael Reese Hospital in Chicago have recently suggested that the development of arteriosclerosis may be promoted by the sensitivity of the body to allergenic compounds, notably certain antibiotics. By using sulfa drugs to produce allergies in forty-two rabbits, the researchers were able in eight months to cause degenerative changes in the arteries of thirty-one of the animals. These changes closely resembled arteriosclerosis in man. According to a press account of Saphir's report, the rabbits' reactions "were not apparent on the surface." It would be very imprudent to assume that such effects are produced only by chemicals that cause severe or noticeable allergies. If the data of Saphir and his colleagues are applicable to man, additives with even minor allergenic properties cannot be dismissed as harmless.

Today more than 3,000 chemicals are used in the production and distribution of commercially prepared food. At least 1288 are purposely added as preservatives, buffers, emulsifiers, neutralizing agents, sequestrants, stabilizers, anticaking agents, flavoring agents, and coloring agents, while from 25 to 30 consist of nutritional supplements, such as potassium iodide and vitamins. The remaining chemicals are "indirect additives" - substances, such as detergents and germicides, that get into food by way of packaging materials and processing equipment. Many chemical additives are natural ingredients, but a large number are not. The artificial substances that appear in food range from simple inorganic chemicals to exotic compounds whose biochemical activity is still largely unknown.

At a time when almost every processed food contains chemical additives or residues, the "misconceptions" of the "Wiley era" must seem like bold anticipations. Sixty years ago the number of chemicals added to food was small. Public concern was aroused primarily by the gross adulteration of food and by the unsanitary practices followed in mills and slaughterhouses. These problems are still with us; as recently as 1958 over 5,000 tons of food was seized by the F.D.A. because of filth and decomposition. But the problem of chemicals in food has reached proportions that would have appalled Wiley, and the incidence of diseases, such as cancer, that can be produced by chemicals in man's environment has increased to an alarming extent. We sense that our food technology has taken a wrong turn. Having achieved the abundance of nutriment it once promised, it threatens to become another factor imperiling man's health and well-being.

# CHAPTER FIVE: ENVIRONMENT AND CANCER

## The Importance of Environment

One of the most challenging problems in public health involves the influence of man's environment on the incidence of cancer. Differences of opinion concerning the extent of this influence are likely to have important practical consequences. If a specialist believes that cancer is caused primarily by genetic factors or by the aging process, his hopes for controlling the disease will focus on advances in surgery, radiology, and chemical therapy. He will tend to regard the occurrence of the disease as inevitable. On the other hand, if he strongly suspects that environmental factors play a major role, he is likely to attach a great deal of importance to cancer prevention. He will regard environmental change as a serious problem requiring careful investigation. Nothing can be done to arrest the aging process or alter the individual's genetic endowment, but almost any environmental factor that influences the incidence of cancer is subject to some degree of social or individual control. The more effectively control is exercised, the lower the incidence of cancer is likely to be.

To what extent, then, are the two points of view supported by evidence and scientific authority?

Fortunately, it has never been established that cancer results from the aging process. At most it has been shown that the highest incidence of certain types of cancer occurs in the later years of life - a fact that can be explained by the longer exposure of older people to cancer-causing substances. "The senescence theory does no more than paraphrase a fact," notes Sigismund Peller; "it fails to indicate how and where the changes are initiated which end in cancer." The theory that cancer is inheritable rests on more impressive evidence and, for a time, occupied a commanding position in cancer research. It had its greatest following in the 1920's, when Maud Slye managed to produce highly inbred strains of mice in which nearly every specimen acquired a cancer. Even the type of cancer and the age at which it appeared could be predicted with reasonable and often astonishing accuracy. Miss Slye advanced the view that cancer is due to a single genetic factor that determines nearly every aspect of the disease - the type of cancer, the site on which it arises, and the age at which it appears. Whether an individual acquired a cancer or not seemed to depend almost entirely upon his genetic endowment.

But the world is not a genetics laboratory in which individuals are mated to prove a point about hereditary cancer. Fortunately, examples of hereditary cancer in man are rare. After further research, it became evident that seemingly hereditary cancers in certain highly inbred strains of mice depended upon a complex of nongenetic factors. In experiments with one of the most "inheritable" forms of the disease - breast cancer in the mouse - Bittner demonstrated "that the kind of milk given to a litter accounts for more than all hereditary factors together. Whether a high or low probability of spontaneous breast cancer may be expected depends primarily upon the

milk (mother versus foster mother taken from a different strain) which the new born mouse of a genetically pure strain sucks in the first twenty-four hours after birth." Bittner's "milk factor" is now believed to be a virus. Clarence Little found that the susceptibility of inbred mice to certain tumor grafts could not be explained without taking at least fourteen different genes into account, and even then many problems arose when the tumors were transplanted. Although a predisposition to cancer may be inherited, it is difficult to believe that an individual is foredoomed to acquire the disease by a genetic factor. "On the contrary," observes Charles Oberling, director of the Institute of Cancer Research in Paris, "cancerous heredity is discovered to be a mosaic of factors that intervene in the most varied domains of the anatomic, physiological, and immunological constitution and cooperate in preparing a soil that is favorable for the emergence of a malignant neoplasm."

It is tempting to add that if the "soil" is prepared by heredity, the "seed" is planted by the environment. A predisposition to cancer is not an absolute that is either present or absent; it is a matter of degree, varying from person to person. It is likely to manifest itself in malignant tumors to the extent that individuals are exposed to carcinogens. The greater the exposure, the higher the incidence of cancer. In fact, cases are known in which the activity of a particular carcinogen largely determines the rate of death from cancer. For example, Peller found that cancer accounted for 51 per cent of the deaths among the radium miners of Joachimsthal in Czechoslovakia. More than half the miners in this community were confronted with the prospect of dying of cancer, an appallingly high percentage. As cancer "normally" accounts for 20 per cent of the adult mortality rate, Peller reasons, approximately 39 per cent of those who might never have succumbed to the disease died of it. In these circumstances, variations in individual predispositions to cancer are so much overshadowed by the potency of a carcinogen (radon) that the "seed" can germinate virtually without any "soil" prepared by hereditary or constitutional factors.

Indeed, one may well ask: What is a "normal" cancer death rate? Is the toll predetermined by genetic factors or will rates vary markedly in different environments? The most reliable evidence at hand suggests that the incidence of cancer and the number of lives claimed by the disease vary appreciably from one kind, of environment to another, even within the same general region. An extensive survey of cancer illness in Iowa during 1951, for example, showed that the incidence of the disease was proportionately almost 40 per cent higher in urban areas of the state than in rural areas. Although large differences could be expected in the incidence of lung cancer, it is noteworthy that a higher rate was reported among city dwellers for all forms of cancer. Urban women had a 25 per cent higher incidence of breast cancer and a 50 per cent higher incidence of genital cancer. Surprisingly, urban men had a much higher incidence of skin cancer (45 per cent), despite the fact that people in rural areas are exposed to greater amounts of sunlight, a natural carcinogen. These variations could not be accounted for by any differences in the quality of medical services or in access to hospitals and doctors. "Rural areas in Iowa appear to have access to the same degree and quality of medical care that urban areas have. Also, the cancer incidence rates for rural areas in metropolitan counties were no higher than for rural areas in remote non-metropolitan counties."

In addition, the incidence of cancer is higher among certain income groups and occupations. The disease occurs most frequently in the poorest strata of the metropolis. Harold F. Dorn and Sidney J. Cutler found that among "white females the incidence of cancer was 14 per cent above average in the lowest income class, but occurred with about equal frequency in the four other income classes... The most consistent relationship is the observation of relatively high incidence



among members of the lower income classes." Although a few forms of cancer show a mild preference for the rich, most types appear with the greatest frequency among the urban poor. Workers who are exposed to industrial carcinogens have a higher incidence of cancer than clerks, and those in nearly all major urban occupations have relatively more cases of the disease than do farmers.

Viewed in this perspective, cancer seems to have certain features in common with tuberculosis. Although the two diseases are fundamentally different in many respects, it is noteworthy that the incidence of both cancer and tuberculosis increases with urbanization. Nor can we overlook the fact that cancer, like tuberculosis, claims the largest number of its victims from among the urban poor. The organs in which the diseases take root "are not only determined by the properties of the particular pathogenic [disease-causing] agent involved, but also by the type or route of contact with it," observes W. C. Hueper. "The conditions of exposure which decide the development of tuberculosis of the lungs and of the intestine - inhalation and ingestion, respectively - are fundamentally no different from those which are responsible for the development of cancers of the skin, bones, lungs, etc., after exposure to radioactive material by skin contact, inhalation, ingestion, or parenteral introduction."

Tuberculosis became pandemic only after man's environment underwent a radical change. Although rural workers were familiar with hunger before the Industrial Revolution, they seldom contracted tuberculosis in large numbers, partly because they lived in open surroundings and engaged in healthful work. The disease, we may recall, turned into the "white plague" when men were crowded into large cities and overworked in dismal factories. It spread among them rapidly even though, in certain cases, they were getting more to eat. Tuberculosis promoting factors overshadowed advances that might well have prevented a high incidence of infection. Today we know that control of the disease is achieved primarily through social advances, better sanitation, and improvement of the standard of living.

The same attention to all the aspects of our environment may be required to control cancer. There is good reason to believe that nearly everything that seriously disturbs the proper functioning of the human organism, particularly many of the toxicants produced by the present-day industrial revolution, contributes to the incidence of the disease. We shall find that cancer is promoted by emotional stress, poor diet, and a large variety of environmental pollutants. While the disease remains a "riddle," to borrow Oberling's word, it threatens to become the major cause of death in the United States and western Europe. In 1945 one out of every eight Americans was expected to die of the disease; today the figure is one out of six. Twenty-five per cent of the population now living in the United States will eventually acquire cancer, and approximately 450,000 new cases of the disease are discovered annually. Sweeping environmental changes in the nineteenth century produced the "white plague" - pandemic tuberculosis; changes in the present century seem to have spawned a "gray plague" - pandemic cancer.

The complexity of the disease should not be underestimated. It is highly improbable that any cancers arise "spontaneously," that is, in the absence of a carcinogen. Whether a carcinogen initiates a series of changes in a cell or is continuously involved in them, the biochemical reactions that lead to malignant tumors often occur in stages, many of which are manifested by abnormalities in pre-cancerous tissue. Whether it is in the stomach, the uterus, or the prostate gland, "cancer rarely appears as a bolt from the blue," Oberling observes. "Almost always it is preceded by nutritional disturbances in the epithelium that masquerade under various names but that are, after all, merely the expression of an abnormal reactivity to certain influences."

Many cancer specialists believe that once a cell is altered by a carcinogen, the change is irreversible; the cell acquires an "imprint" and transmits it to all its descendants. Whether or not a cancer develops depends upon many factors, such as the potency of the carcinogen, the extent of exposure to other chemical and physical agents, and the individual's constitution. Malignant cells may become detached from a localized cancer and enter the blood stream without producing new tumors. Apparently, certain resistance mechanisms must be overcome before malignant cells can take root elsewhere in the body and produce invasive, secondary cancers.

A cancer can be induced by a single chemical agent or by several, by small, irregular doses of the carcinogen or by a few large ones. The disease may not manifest itself for many years, even decades. A carcinogen may reach man by way of the air he breathes, the fluids he drinks, and the food he eats. It may harm a specific part of the body or the organism as a whole. Any powerful agent or stimulus that alters the normal functioning of human metabolism over a long period of time is potentially carcinogenic. Let us concede that the word "normal" has yet to be defined and that each individual has different biological needs. But let us also acknowledge that the incidence of cancer can be increased enormously by reckless changes in man's environment, that millions of lives are placed in jeopardy by thoughtless alterations in man's manner of life, diet, and physical surroundings.

## The General Environment

What are some of the general, or nonspecific, factors that influence the onset and progress of cancer? If this question is often difficult to answer, the reason is not that these factors are too few; on the contrary, there are too many of them, and the problem is to decide which ones are the most important. There is evidence that both the occurrence of a cancer and its course are influenced by the subject's emotional make-up, his diet, and his occupation. The adequate treatment of a cancer, in turn, requires knowledge not only of surgery, radiation, and chemical therapeutics but also of the patient's character and environment. Although the course of many cancers is generally predictable, individual responses to treatment vary so widely that a specific cancer that usually causes death within a few months can, in some cases, be controlled for several years.

Emotional stress is an important element in the progress of certain cancers. At the annual meeting of the American Cancer Society in 1959, several cancer specialists focused attention on the role that anxiety seems to play in the onset and course of malignant tumors. Drawing upon his experiences as a radiologist, Eugene P. Pendergrass, the outgoing president of the society, observed that even if psychological factors do not determine the eventual outcome of cancer, they seem to influence the development of the disease. "I personally have observed cancer patients who had undergone successful treatment and were living well for years. Then an emotional stress such as a death of a son in World War II, the infidelity of a daughter-in-law, or the burden of long unemployment seems to have been a precipitating factor in the reactivation of their disease which resulted in death." A similar viewpoint was expressed by John B. Graham, of the Roswell Park Memorial Institute in Buffalo. "The adversities and despairs that these people [cancer victims] are subject to, and their responses to them, are indeed factors in the development of cancer and the effectiveness of treatment." At a press conference, Graham added: "It has seemed to us in some

cases that despair precedes cancer. I would not say it is a cause, but it may be a factor which decides when cancer will develop.”

In view of what we know of Selye’s work on stress and the adrenal corticoids, these conclusions should not be surprising. Cortisone is used effectively to delay death in cases of such hopeless cancers as acute leukemia. The temporary remissions achieved by this hormone are often striking. After being treated with cortisone, a victim of acute leukemia often seems to be on the point of complete recovery, although in time the cancer invariably overcomes the effects achieved by the hormone. There are reasons for suspecting that, just as cortisone inhibits the growth of certain cancers, other adrenal hormones sustain and even propagate cancers of the breast and prostate gland. By removing the adrenal glands of patients suffering from these tumors, physicians often gain control of the disease for long periods of time. New methods are replacing adrenal surgery, but the inhibition of the production of corticoids is a basic technique in managing both types of cancer. According to Selye, the value of adrenal surgery in certain cases of cancer “would suggest that there are adrenal factors which stimulate cancer formation.”

It is tempting to speculate whether emotional stress, by influencing the output of the adrenal glands, contributes significantly to the rising incidence of cancer. The adrenal cortex normally secretes male sex hormones (androgens) and perhaps female sex hormones (estrogens). The corticoids are also directly involved in the secretion of hormones by the male and female sex glands. Many experiments have shown that injections of estrogens induce mammary cancer in cancer-prone mice, and intensive use of estrogen to control cancer of the prostate gland in men has been followed, in some cases, by breast cancer. “There can be little doubt that endocrine imbalance is the basis for chronic cystic mastitis, or *maladie de Reclus*, which is characterized by fibrous nodules that are sometimes interspersed with cysts, and it has been shown by Warren and by Foote and Stewart that cancer is five times as common in breasts affected by this condition as it is in normal ones.”

Oberling’s opinion, advanced in 1952, received strong support several years later from the results of autopsies performed on 207 women with cancers of the breast. The investigators found evidence of marked endocrine imbalances and particularly of prolonged estrogenic estrogens are steroids, and there is a close resemblance between the chemical structure of the steroid hormones and that of certain carcinogens. Some of these carcinogens, in turn, have a mild estrogenic activity; that is, they produce, on a smaller scale, effects similar to those produced by estrogens and corticoids. There is a possibility either that excessive secretions of the steroids turn pre-cancerous cells into cancerous ones or that the hormones are actually degraded into carcinogens. At any rate, the apparent relationships between stress and cancer and between the steroids and carcinogens can hardly be ignored.

“There is solid evidence that the course of disease, in general, is affected by emotional stress,” Pendergrass observes. “A growing list of authorities have lent support to this field of investigation. Foremost among these is Dr. Hans Selye who devoted much of his life to the subject. In order to learn about such stresses, one must explore beyond the usual limits of a clinical history. This takes time. Busy doctors may be unable to give the time to secure a good history concerned with environmental, constitutional and other factors; a history of emotional stress, or just the opposite; a climate of happiness and security. Could this not be an area for another discipline in medicine, [for] a social scientist for instance; or maybe this is a field where the social worker should expand his or her activities. I believe that research in this area will, almost certainly, lead into investigations of factors that are susceptible to control hormonal systems and other general

metabolic influences. Thus, we as doctors may begin to emphasize treatment of the patient as a whole, as well as the disease from which the patient is suffering. We may learn how to influence the general body systems and through them modify the neoplasm which resides within the body."

Cancer does not always grind inexorably to its logical end. At least 150 spontaneous remissions of cancer in man have been carefully authenticated by reputable scientists. A number of these tumors had already metastasized widely and were regarded as incurable. As Oberling observes: "... it is difficult to estimate the frequency of spontaneous cure because cancer is generally not recognized until it has reached an advanced stage. It is entirely possible that many malignant growths disappear in their initial stages, leaving no trace behind. This, of course, is the purest speculation."

But Oberling's speculation is not reckless. Research has clearly demonstrated that organisms possess mechanisms for resisting cancer. According to a report by the Sloan-Kettering Institute for Cancer Research, defense mechanisms have been observed in mice receiving transplants of a highly malignant cancer which usually kills 95 per cent of its victims in three weeks. "If these animals were given a small dose of material extracted from yeast cells called zymosan, they defended themselves vigorously against the cancer. Instead of killing the mice, the cancers were gradually dissolved until they disappeared entirely. The animals were then completely cured. No cancer has ever returned, and strong immunity to a second implantation has been demonstrated as long as 11 months after the first growth was initiated. Remarkably, these cancer cells grown in tissue culture are not disturbed at all when put in direct contact with zymosan. This indicates that zymosan does not inhibit the cancer directly but acts in some way in mice to enhance their natural defenses, tipping the scales in favor of the endangered host and against the cancer." The yeast extract, unfortunately, "is too toxic in man for clinical use."

This line of research is important because high resistance depends not only on hereditary factors but also on good nutrition, a sound state of mind, and balance in work and play. It is fairly well established that the high incidence of liver cancers in depressed areas of the world is due in large part to dietary deficiencies of protein and possibly the B vitamins. Rats nourished on similarly deficient diets have a high incidence of the disease, although it is rare in animals that receive the same food supplemented with wheat, yeast, or powdered liver. Dietary factors may also contribute to the relatively high incidence of chorioepithelioma (a cancer of the uterus) in the Far East. In general, however, experimental data are inconclusive for other forms of cancer because the relationship between animal tumors and nutrition varies with the strain and species used. "It does appear that maintenance of body weight at a minimum compatible with good health may prevent or delay the development of cancer in many individuals," observes Helen N. Lovell in a review of the available evidence. "A diet adequate in all nutrients seems to be most desirable. Many believe the oral and pharyngeal symptoms of chronic riboflavin and nicotinic acid deficiency are precancerous factors."

Despite the influence of all the factors we have been discussing, many well-nourished and serene individuals perish from virulent cancers fairly early in life. Why? What are some of the factors that might produce malignant tumors in persons whose diet, habits, and outlook are sound? These questions introduce a formidable problem. Man is exposed to a large number of cancer-causing agents; some of them are natural in origin and virtually impossible to avoid, but a substantial number of them are man-made. A few of these artificial agents are useful in medicine, but the majority can be either completely dispensed with or at least used in such a way that they

do not affect the general public. The presence of these agents in the human environment has aroused a great deal of concern, and their removal requires vigorous social action.

## Chemical Carcinogens

Man is capable of producing at least two types of agents that have cancer-causing properties. One of them, ionizing radiation, will be discussed at some length in the following chapter. Our principal concern here will be with the chemical carcinogens, ranging from confirmed cancer-causing substances to those that are highly suspect.

The suspicion that chemicals in man's environment can cause cancer first arose nearly two centuries ago, when Sir Percival Pott, a London surgeon, identified "chimney sweep's disease" as cancer of the scrotum. Pott unerringly pointed to soot, the tarry material formed by the combustion of solid fuels, as the cause of this malignant tumor. In the eighteenth century the job of cleaning chimneys was given to boys who were small enough to negotiate the elaborate flues in the London homes of that period. As the boys worked, their trousers rubbed soot into the sweat glands of the scrotum. In later life, perhaps ten or fifteen years after this kind of work had been abandoned, the scrotum would begin to ulcerate and then develop a cancer which invariably claimed the life of its victim. In 1914 two Japanese investigators, K. Yamagiwa and K. Itchikawa, succeeded in developing skin cancer in 41 of 178 rabbits who had received applications of tar to the internal surface of the ear. Three years later H. Tsutsui was able to similarly induce tar cancer in mice.

The success of these Japanese investigators met with warm professional appreciation - and for good reason. Their work opened a new era in cancer research - the study of chemical carcinogens - and with it there arose a host of disconcerting problems concerning the behavior of these agents in men and animals.

Yamagiwa and Itchikawa would not have been able to produce tar cancer of the skin if they had used guinea pigs instead of rabbits. Although tar induces cancer in man, it does not produce the disease in the guinea pig, an animal commonly used in experimental work. In all probability, the Japanese investigators would also have been unsuccessful if they had used rats. Despite repeated attempts from 1914 on, cancer of the skin could not be produced in this animal through applications of tar until 1935. They might also have failed with dogs, whose response to tar is "sporadic and inconstant," in Oberling's words. In short, evidence that tar is carcinogenic in animals was acquired partly through luck and partly through patience. Yamagiwa and Itchikawa had the good fortune to select an animal that is more susceptible to tar cancer than other experimental subjects, but they had to persevere through at least 150 applications of the carcinogen before malignant tumors were induced.

Their experiment was not the first attempt to induce cancer in animals by means of tar. Similar efforts were made in 1888, 1890, and 1894, and again as late as 1913, by Haga, another Japanese investigator. All the attempts failed. The experiments in the last two decades of the nineteenth century were performed mostly on dogs and rats. Haga even turned to the rabbit as a subject, but he failed to keep at the tar applications long enough. The medical pundits of the day thereupon concluded that chemical carcinogenesis did not exist. "For decades these few negative [experimental] results weighed more heavily than numerous observations to the contrary in chimney sweeps, tar, paraffin and dye workers, and mule spinners," Peller observes. "... only after positive

experimental results on animals had been published, did cancerologists change their opinions. It was formerly considered scientifically sound to deny the relationship; now it became sound to accept it. If Yamagiwa and Itchikawa (1914) and Tsutsui (1917) had chosen the rat for their experiments, instead of rabbits and mice, then the tar genesis of certain skin epitheliomas in man and the theory of irritation in cancer would have been 'expertly' denied for another 17 to 20 years, and the whole development of chemistry of cancerogens would have been retarded."

The same story can be told about beta-naphthalamine, a compound used in the preparation of a number of coal-tar dyes. Beta-naphthalamine, which induces cancer of the bladder, is one of the most potent carcinogenic substances in man's environment; it has claimed hundreds of lives among workers in the synthetic-dye industry. Attempts were made as early as 1906 to induce cancer in rabbits by means of synthetic dyes, including betanaphthalamine, but the experimenter, B. Fischer, did not persist long enough in his efforts. After producing cancer-like cells that regressed spontaneously when injections of the carcinogens were stopped, Fischer concluded that the dyes did not induce occupational cancers. This conclusion was generally accepted by the medical profession. Not until the late 1920's were cancers produced experimentally by beta-naphthalamine, but even then rabbits proved to be poor subjects and rats and mice were found to be resistant to the compound. In 1938, more than thirty years after Fischer's work, Hueper and his coworkers discovered that the only animal that readily contracted cancer of the bladder from beta-naphthalamine was the dog.

The reason for inflicting these details on the reader should be fairly obvious. Cancers in animals "cannot provide irrefutable proof of the safety or carcinogenicity of a substance for the human species," observes a report by the Food Protection Committee of the National Academy of Sciences. The committee adds that "it is perhaps reassuring that the known carcinogenic responses of humans to certain chemicals are similar in many ways to those seen in experimental animals" - but the qualifying words "perhaps," "certain," and "in many ways" carry a heavy burden. Actually, some carcinogens are handled quite differently in man from the way they are handled in common experimental animals. Beta-naphthalamine, for example, is not carcinogenic as such. In the human body, however, it is metabolized into the carcinogen 2-amino-1-naphthol, whereas resistant animals either fail to produce this metabolic compound or create it in very small amounts.

Many subtle physiological differences between animal species - indeed, between individuals in the same species - are likely to affect the potency of a chemical carcinogen. "The only universal carcinogen is apparently ionizing radiation," Hueper notes. Whether or not a cancer is produced by an environmental carcinogen depends on the organ with which it comes in contact, on the solubility of the carcinogen in the body's fluids and therefore "on the speed of removal from the site of primary contact of a carcinogen, upon the metabolism of the carcinogen, on its route of excretion and on the tissue or organ of retention or deposition of a carcinogen. The target organ may vary in different species." Hueper concludes that the ability of a carcinogen to affect different species and organs in different ways seems to depend on the distinctive metabolic processes of the animals involved.

These factors apparently account for the fact that several types of cancer that are common in man are difficult to produce in animals. For example, until very recently the most common form of stomach cancer in humans (adenocarcinoma) could not be produced in rabbits, mice, rats, and dogs by feeding them various carcinogens. On the other hand, adenocarcinomas of the small intestine, while rare in man, are fairly easy to produce in animals. The lung tumors produced in mice do not resemble the lung tumors in humans that have aroused so much professional

and public concern. Many cancer specialists even disagree on whether these tumors in mice are malignant or benign. Spontaneous regressions of cancer in mice, animals widely used in cancer research, are not uncommon, but the regression of diagnosed cancers is very rare in man.

When the researcher finds that a particular compound does not induce cancer in rats, mice, or dogs, he can only hope that it will not cause the disease in man. He can never be certain of this unless carefully controlled experiments on a large number of human volunteers are continued for decades without causing a cancer that is clearly attributable to the particular chemical. Experiments with animals are likely to be more painstaking if the compound being tested is chemically related to a number of known carcinogens. But there are no clear-cut groups of carcinogenic substances. Some known carcinogens are highly complex hydrocarbons; others, such as chromium, nickel, and arsenic, usually reach man as simple inorganic compounds. Often the most trivial chemical change can transform an apparently non-carcinogenic substance into a potent carcinogen. A mere shift of the NH<sub>2</sub> group in alpha-naphthalamine, a non-carcinogenic compound, from one position to another in the molecular ring of the chemical produces the carcinogen beta-naphthalamine.

Many carcinogens have been able to enter man's environment because of the relative crudeness of experimental techniques. Even today, despite advances in testing methods, carcinogenic properties are being discovered every few years in established food additives. At least ten chemicals listed as recently as 1956 by the National Academy of Science in *The Use of Chemical Additives in Food Processing* are currently suspected of being cancer-causing agents. These include a cheese preservative (8-Hydroxyquinilone), a flavoring agent for root beer (safrole), a cheese stabilizer (carboxymethyl cellulose), and several coal-tar dyes. Perhaps the worst offenders are the dyes, notably Yellow AB and OB, which were used for decades to color butter, cheese, cake, candy, cookies, drugs, and cosmetics. When ten commercial samples of these food colors were analyzed by Walter D. Conway and Elizabeth J. Lethco, of the National Cancer Institute, they were found to contain very large residues of beta-naphthalamine, ranging from a low of 76 to a high of 908 parts per million.

Although recent legislation stipulates that no carcinogen may be used as a food additive, there are several noteworthy exceptions. Lead arsenate, for example, is still employed as an insecticide in orchards and vineyards. Residues of the compound (usually 7 parts per million) are allowed to remain on such common fruits as apples, pears, plums, peaches, cherries, and grapes. "It has been known for many years that exposure to arsenicals produces a certain type of cancer of the skin," Francis E. Ray, director of the University of Florida's Cancer Research Laboratory, told the Delaney Committee. "More recent evidence is that inhalation of arsenic dust - and sprays - may cause cancer of the lungs. It is possible that other types of internal cancer may be caused by the long-continued ingestion of so-called nontoxic doses of arsenicals." Ray declared that the use of arsenicals on crops "should be prohibited." The demand, although reiterated by many outstanding cancer specialists, has largely been ignored.

"While not within the scope of this investigation," Ray added, "it may be mentioned that female sex hormones [estrogens] have been incorporated into cosmetics. These hormones have been shown to induce cancer in female animals when administered for a prolonged period. Their use in cosmetics should be prohibited." (The most commonly used estrogens in facial creams are estradiol and estrone. Hueper warns that although estrogenic creams are applied to the skin, they occasionally produce systemic effects.) Thus far, however, no action has been taken to forbid the use of estrogens in facial creams. In fact, the use of synthetic hormones has been extended, not re-

duced. For example, synthetic hormones, notably stilbestrol, are now added to 85 per cent of the cattle feed produced in the United States. A woman who purchases a cosmetic that contains hormones exercises a choice, but a consumer who acquires residues of stilbestrol in meat belongs to a "captive" population whose wishes have not been consulted by food producers or government agencies. Whether the stilbestrol fed to livestock makes its way into meat has been the subject of heated controversy. Regulations prepared by the F.D.A. stipulate that daily feedings of the drug should not exceed 10 milligrams for steers and 2 milligrams for sheep. According to the F.D.A., residues of stilbestrol are avoided when hormone-containing feed is withdrawn forty-eight hours before slaughtering. Actually the evidence for this claim is equivocal. Although F. O. Gossett and his coworkers found that residues did not appear in meat when the F.D.A.'s regulations were followed, C. W. Turner detected traces of stilbestrol in the lungs and kidneys of animals slaughtered forty-four hours after the prescribed 10-miligram dosages had been withdrawn.

Experimental work on mice by a group of researchers at the National Cancer Institute indicates that stilbestrol is a highly potent drug. Practically all the mice that had received a subcutaneous implantation of 1 milligram of the synthetic hormone acquired tumors of the testicles within seven months. When the pellet was removed after eight weeks, no gross tumors developed, but when it was reimplanted twenty-four weeks later, the incidence of tumors rose sharply, as though the pellet had never been removed. The effect of a brief stimulus is never lost; exposure to stilbestrol seems to be cumulative.

Thousands of man-made chemicals with undetermined properties enter our food supply, water, and air. Some may be co-carcinogens; these lack significant cancer-causing properties of their own but increase the potency of known carcinogenic agents. Others may be weak carcinogens whose cancer-causing effects are additive and synergistic. Any such carcinogens and cocarcinogens would escape the attention of the researcher unless they were brought into combination with one another. But this is a rare experimental procedure. "Potential carcinogenic contaminants," Hueper warns, "also may be introduced into foodstuffs if vegetables, fruits, fish, oysters, and livestock are grown on soil or in water polluted with known carcinogens, such as radioactive matter, arsenicals, selenium and polycyclic hydrocarbons contained in ship fuel oils, since these chemicals may be taken up and stored by the vegetable and animal matter growing in such contaminated media... There exists also the possibility that originally noncarcinogenic additives and contaminants may interreact with each other or with food constituents and form new compounds possessing carcinogenic properties in the foodstuffs. They may be produced under the influence of processing procedures or during the preparation of food in the kitchen. Plastics used as wrapping material, sausage skins and coating material of fruits, cheese, meat, butter, and can linings may carry similar hazards."

These are not irresponsible vagaries. A number of chlorinated hydrocarbons, such as DDT, seem to have mild tumor-inducing effects. Nearly all insecticides are dissolved in petroleum distillates, many of which are also suspected of being carcinogens. Crude and semi refined paraffin waxes, from which cosmetics and food containers are made, have carcinogenic properties and, in some cases, contain residues of highly potent cancer-causing substances. Hans L. Falk, Paul Kotin, and Adele Miller found that the protein in ordinary milk could eluate, or extract, hydrocarbons from the wax coating of their containers. The investigators had deliberately impregnated the wax with these hydrocarbons so that the eluant properties of milk could be tested. "However," they write, "an analysis of several dairy waxes revealed the presence of a small amount of



1,2,5,6-dibenzanthracene of the order of one part per million." Dibenzanthracene, a highly potent carcinogen, appears as an impurity in many semi-refined paraffins.

It is difficult to specify all the potential hazards to public health that are created by saturating man's environment with poorly tested, exotic chemicals. Many cancers are stealthy; they develop slowly and imperceptibly. Decades may pass before mistakes committed today finally bear their malignant fruit; we may pay a heavy price in human life, not so much as a result of brief exposures to a few potent carcinogens as because of the exposure of millions of individuals to small quantities of "harmless" compounds over long periods. The potent carcinogens "by their very strength are almost sure to be discovered clinically," Kotin writes. "In essence, a strong carcinogen identifies itself by the very circumstances which aroused suspicion in the first place. It is assuredly the less potent carcinogens that seem to be more important in human cancer, and it is these that provide the real problem for evaluation."

## Environment and Lung Cancer

The incidence of one kind of malignant tumor, lung cancer, has begun to increase at an appalling rate. "A century ago, Rokitsky of Vienna, the most experienced pathologist of his time, considered lung cancer a rarity" Peller observes. "In other and older books with detailed descriptions of cancer, the lungs are not mentioned at all, whereas cancer of the larynx and of the nose are discussed. Fifty years ago, in hospitals, larynx cancer in the United States was 1.5 times as frequent as lung cancer. In 1947-48, 9 per cent of all fatal cancers, namely 18,144, developed in the respiratory organs and only 1,870 of them originated in the larynx. The number of recorded lung cancers is rising more rapidly than that of any other subgroup."

Although it could be claimed that before X rays were discovered many lung cancers were mistaken for other respiratory disorders, the opinion of an experienced, conscientious medical man such as Rokitsky cannot be ignored. If lung cancer had been a common disease a century ago, it would not have been regarded as a medical curiosity by many of the leading pathologists of the day. During the last five decades the incidence of lung cancer increased at a startling rate, and today the disease is very common. In 1914 seven white American males per million died of lung cancer. By 1956, this figure had reached 284 a fortyfold increase in less than half a century.

It is difficult to attribute these higher figures to improvements in diagnostic technique. By the 1930's, X rays were being used extensively in the United States and biopsies involving the microscopic analysis of cancerous tissue were frequently performed. Nevertheless, the number of deaths from lung cancer among American males rose steadily after 1930 until it had increased 500 per cent by 1951. Even more conclusive evidence against the "diagnostic improvement" argument is supplied by data from the Copenhagen Tuberculosis Station in Denmark. "In a tuberculosis referral service, used extensively by local physicians, where diagnostic standards and procedures including systematic bronchoscopy remained virtually unchanged between 1941 and 1950, the lung-cancer prevalence rate among male examinees increased at a rate comparable to that recorded by the Danish cancer registry for the total male population," Jerome Cornfield and his colleagues observe in an excellent review of the lung cancer problem. "This can be regarded as evidence that the reported increase in Danish incidence is not due to diagnostic changes."

It is equally difficult to attribute the rise in the number of cases of lung cancer to the increased longevity of the population. Whatever may be the factors that account for the high incidence

of cancer in older people, careful study has shown, Cornfield observes, that "only one sixth of the over-all increase in lung-cancer mortality among males in the United States (from 4 to 24 deaths per 100,000 males between 1930 and 1951) could be attributed to an aging population. Similar findings have been presented for England and Wales... Allowance for increased average age of the population could account for only half this rise in lung-cancer mortality, with a 24-fold difference between 1900 and 1953."

Nor is it a convincing argument that the rise in deaths from lung cancer is due to cancers that begin in one part of the body and later migrate to the lungs. Autopsies have proved this to be a fallacy. Cornfield and his associates reviewed thirteen series of such autopsies, the first begun early in the present century and the last completed in the 1950's. These autopsies support the claim that mortality from primary lung cancer has increased sharply during the past fifty years.

The inescapable conclusion seems to be that the rising incidence of lung cancer is due to recent changes in man's environment and manner of life. What are the changes? The majority of American biostatisticians and cancer specialists believe that cases of lung cancer are multiplying because of the increased consumption of cigarettes, and they have collected an enormous amount of statistical evidence to support this belief. "Twenty-two... studies of smoking in relation to lung cancer have now been carried out independently in eight different countries," notes E. C. Hammond, of the American Cancer Society. "In every one of these, a far larger proportion of smokers (particularly heavy cigarette smokers) was found among lung cancer patients than among people without this disease. This has been shown for both men and women." Hammond adds that "similar studies have shown an association between smoking and cancer of the buccal cavity, cancer of the larynx, cancer of the bladder, coronary artery disease (the most common form of heart disease), and Buerger's disease (a circulatory disease of the extremities)."

Thus far the most important attempt to correlate the rising incidence of lung cancer with increased smoking has been the survey made under the direction of E. C. Hammond and Daniel Horn for the American Cancer Society. The society mobilized 22,000 volunteers as researchers, and asked each of them to have about ten men between fifty and sixty-nine years of age complete a questionnaire on their smoking habits. Precautions were taken to query only individuals who were not seriously ill, who apparently were not suffering from lung cancer, and with whom the research volunteers enjoyed some measure of personal contact, so that thorough follow-ups could be made. Nearly 190,000 acceptable questionnaires were obtained during the first half of 1952. Almost 188,000 were followed up by the volunteers through October 1955. A careful study of the death certificates of about 12,000 men who died during the three-year period yielded remarkable results. Comparing smokers with nonsmokers in the same age groups, Hammond and Horn found that the general death rate was 9 per cent higher for occasional smokers, 12 per cent higher for pipe smokers, and 68 per cent higher for cigarette smokers. The death rate for cigarette smokers increased progressively with the quantity of cigarettes smoked, nearly doubling with a rise in consumption from a half pack to two or more packs daily. It was found that the incidence of lung cancer among cigarette smokers was almost twice as high as it was among nonsmokers. Comparing moderate smokers (a half pack daily) and heavy smokers (two or more packs daily) with nonsmokers, Hammond and Horn found that the ratio of death from lung cancer soared to 17 to 1 and 60 to 1, respectively.

Those who maintain that there is no relationship between lung cancer and smoking have been placed in an untenable position. At first it was held that there was no direct evidence to implicate tobacco tars in cancer in animals. This contention was shaken when at least six different labo-

ratories reported that such tars induced skin cancer in mice. It was then claimed that although tobacco tars may cause skin cancer in mice, it had not been shown that they could cause lung cancer in mice, men, or any other species of animal. This argument is difficult to sustain, at least as far as men are concerned. In a co-operative project initiated in 1954 under the direction of two leading American pathologists, Oscar Auerbach and Arthur Sout, the entire breathing apparatus was systematically removed from all individuals autopsied at the Veterans Hospital in East Orange, New Jersey, and at eleven hospitals in New York State. The investigators were able to obtain reliable histories of smoking on 402 of the subjects, all of them white males, 63 of whom had died of lung cancer. After preparing nearly 20,000 usable slides of lung tissue from the 402 subjects and carefully examining each slide under the microscope, the pathologists found that tissue abnormalities (changes in the epithelium) appeared in only 16.8 per cent of the slides from nonsmokers, in 92.3 per cent of those from light smokers, in 97.4 per cent of those from moderate smokers (a half pack to a pack daily), and in nearly 100 per cent of the slides from those who smoked more than a pack daily. The changes in the lung tissue from atypical, potentially cancerous cells to invasive, cancerous cells increased with the average intake of cigarettes. Focusing their attention on all the subjects who had died from causes other than lung cancer, Auerbach and Sout found that 22.6 per cent of the slides from heavy smokers had atypical cells and 11.4 per cent had cancerous cells. On the other hand, only 0.2 per cent of the slides from nonsmokers had atypical cells and none had cancerous cells.

However, disinterested critics of the theory that smoking and lung cancer are related have performed a very useful function. By looking for other factors besides smoking, they have drawn a great deal of attention to the role that air pollution plays in producing the disease. The relationship between air pollution and lung cancer has largely been ignored despite evidence that lung-cancer rates are higher in cities than they are in rural areas. But as more research is done, zealots on both sides in the lung-cancer controversy are moving toward a more balanced position. An impressive amount of statistical evidence implicates air pollution as well as smoking in the rising incidence of lung cancer. White South African males, for example, are probably the heaviest smokers of packaged cigarettes in the world, and the number of deaths from lung cancer among them has increased from 11.7 per 100,000 in 1947 to 24.6 in 1956. But South Africa presents an interesting opportunity for statistical research. The country has acquired a large number of British immigrants, most of whom came from English cities with heavily polluted air. Is the incidence of lung cancer higher among British immigrants than among native-born South Africans? After a careful statistical study, Geoffrey Dean, of the Provincial Hospital in Port Elizabeth, South Africa, established that in the forty-five-to-sixty-four age group, deaths from lung cancer were 44 per cent higher among a group of British male immigrants than among native-born males. The incidence of the disease rose with the age at which immigration occurred, indicating that longer residence in England increased the possibility of dying from lung cancer. The difference in the death rate between native-born and British-born males could not be explained by differences in cigarette brands; the two groups smoked very much the same brands. But Dean's data in no way indicate that prolonged smoking is not hazardous. On the contrary, the steadily rising rate of death from lung cancer observed in both groups of males supports the contention that cigarette consumption plays a major role in causing the disease.

The air over the metropolitan districts of the United States and Europe contains a large variety of known carcinogens. Perhaps the most potent of these agents are the so-called polycyclic hydrocarbons, such as benzpyrene and anthracene. By painting the skin of mice with benzpyrene

three times weekly for six months, E. L. Wynder and his coworkers were able to produce cancers in nearly half the animals. An individual who smokes a pack of cigarettes a day acquires about 60 micrograms (millionths of a gram) of benzpyrene a year. If he lives in Helena, Montana, he inhales 0.8 micrograms of benzpyrene from the air annually; in Los Angeles, he inhales 20; in Detroit, 110; and in London, 320. That is, he acquires the equivalent of the benzpyrene in a third of a pack of cigarettes daily merely by breathing the air in Los Angeles, the benzpyrene in nearly two packs from the air in Detroit, and the benzpyrene in five packs from the air in London. It should not be surprising to learn that death rates for lung cancer among males in England are more than twice those in the United States.

Kotin found that when an efficient automobile engine revolves 500 times per minute for one minute, it produces a gasoline exhaust containing 235 micrograms of benzpyrene. When the engine is accelerated to 3500 revolutions per minute, the amount of benzpyrene in the exhaust decreases to 10 micrograms. A congested thoroughfare cluttered with idling or slow-moving motor vehicles is a hazard to human lungs. Individuals who spend a large part of their time in such areas, irrespective of the particular metropolis in which they live, are likely to acquire a lifetime dosage of benzpyrene that is thousands of times greater than the amount required to produce cancer in mice.

In addition to smoking and air pollution, socioeconomic factors have been found to play a role in the incidence of lung cancer. It is a tempting hypothesis that susceptibility to the disease is increased by poor nutrition, economic insecurity, and low physical resistance. "The existence of other important lung-cancer effects associated with such characteristics as socioeconomic class cannot be questioned," Cornfield and his coworkers state. "Cohart found that the poorest economic class had a 40 per cent higher lung-cancer incidence than the remaining population of New Haven, Connecticut. Results of the 10-city morbidity survey [by Dorn and Cutler] have revealed a sharp gradient in lung-cancer incidence, by income class, for white males, which is consistent with Cohart's findings. Since cigarette smoking is not inversely related to socioeconomic status, we can agree with Cohart '... that important environmental factors other than cigarette smoking exist that contribute to the causation of lung cancer.' these and other findings are convincing evidence for multiple causes of lung cancer. It is obviously untenable to regard smoking of tobacco as the sole cause of lung cancer." (This conclusion is apparently shared by Hammond and Wynder, who not only were coauthors of Cornfield's report but also played an outstanding role in focusing public attention on the hazards of cigarette smoking.)

What can we learn from these studies? There no longer seems to be any doubt that the rising incidence of lung cancer is due to recent changes in our synthetic environment. So compelling are the data now at hand that virtually the entire scientific community has been obliged to accept this conclusion. One can only wonder why it was not accepted earlier. The growing incidence of lung cancer was noted as early as 1929 in the German Journal for Cancer Research by Fritz Lickint, who thought that the disease was related to smoking. In 1932 the same relationship was explored by W. D. McNally in the American Journal of Cancer Research. Lickint and McNally were followed by other investigators, including Alton Ochsner, who wrote on the subject in 1941, but the scientific community remained largely unmoved. More than a decade passed before Hammond and Horn finally presented the problem of the relationship between lung cancer and smoking in a form that was too compelling to be ignored. Until then, the rise in the number of cases of lung cancer was generally attributed to genetic factors or to increased longevity.

It should be noted that it has taken many years for an obvious link between environmental changes and the rising incidence of a major disease to gain wide acceptance among scientists. Because of its highly charged social, economic, and political implications, man's environment is an arena that scientific research tends to enter with reluctance. There is a strong disposition to probe heredity, a more neutral field, or to dismiss grave problems of disease as the consequence of greater longevity. But now the evidence of the direct connection between the rising incidence of lung cancer and changes in man's environment has affected this traditional approach profoundly. We now have good reasons for questioning whether any type of cancer need burden mankind as heavily as it does today. We have begun to take a closer look at the irrationalities in our synthetic environment. Perhaps we shall begin to eliminate them. But we cannot wait indefinitely before making man's environment and manner of life more rational. Mortality from cancer is rising steadily. In the United States, known deaths from the disease increased 22 per cent between 1940 and 1959, an increase that can scarcely be accounted for by any monumental improvements in diagnostic technique. Recently a survey of 610 women by the New York City Cancer Committee showed that more than a third had symptoms suggestive of malignant tumors or a pre-cancerous condition. None of the women was more than forty-two years old. Robert A. Loberfeld, vice president of the committee, is quoted in a news item as describing the situation as "shocking." Cancer has even reached epidemic proportions. At the Fourth National Cancer Conference, in September 1960, Lester Breslow reported that "tens of thousands" of trout in western hatcheries suddenly acquired liver cancers. Apparently the disease was "associated with a new type of diet," not with a virus.

"Technological changes affecting man's environment are being introduced at such a rapid rate and with so little control that it is a wonder man has thus far escaped the type of cancer epidemic occurring this year among the trout," Breslow told his colleagues. "Or have we? Lung cancer is not too dissimilar except that the time period is decades, not weeks. If community air pollution of the types now prevailing or being introduced by technological changes is proved to be a causative factor in lung cancer, we would be dealing with exposure of millions of people. New pollutants are frequently added nowadays to community air through changes in industrial process, fuel composition and the like. They are added for reasons of economy or efficiency in industry or transportation - essentially the same reasons given for changing the diet of the fish. It is not inconceivable that although cigarette smoking has been the major factor in the lung cancer epidemic during the first half of the 20th century, some form of community air pollution could be responsible for an even larger epidemic of the disease during the second half of the 20th century."

# CHAPTER SIX: RADIATION AND HUMAN HEALTH

## The Effects of Radiation

It is hardly necessary to emphasize that since the explosion of a nuclear weapon at Alamogordo, New Mexico, in July 1945 ionizing radiation has become the most serious threat to man's survival. If nuclear weapons are further developed or increased in number, it is quite conceivable that a future war will virtually extinguish human life. Grave as this danger may be, ionizing radiation is associated with a number of subtle hazards that warrant equal public concern. "Today... sources of ionizing radiation are rapidly becoming more and more widely used," observes a team of radiation specialists for the U. S. Public Health Service. "Each atomic reactor produces the radioactive equivalent of hundreds of pounds of radium. Radioactive substances are used in increasing numbers of hospitals, industries, and research establishments. X-ray machines are encountered in tuberculosis surveys, in shoe stores, in physicians' offices and in foundries. Potentially, ionizing radiation has come to affect the environment of every member of the community."

Radioactive elements are among the most lethal toxicants in man's environment. As little as four micrograms (one seven-millionth of an ounce) of radium is capable of producing cancer in man years after lodging in his bones. Not all radioactive elements are dangerous in the same way as radium. Some are distributed differently in the body and are not retained for long periods; others, although retained for years, emit different kinds of radiation. Strontium-90, for example, is rated about one tenth as lethal as radium, although it, too, lodges primarily in the bones. Attempts to compare the potency of the two elements in quantitative terms, however, can be somewhat misleading. Radium causes biological damage through the emission of alpha particles, whereas strontium-90 is hazardous to living things because it is an energetic emitter of beta particles. "Leukemia has been observed to occur in radium patients, though not as a prominent phenomenon," observes W. F. Neuman, of the University of Rochester. "Leukemia is, however, a common finding in people who have suffered irradiation of the bone marrow or of the whole body. Since the beta rays from strontium-90 are more penetrating than the alpha rays from radium, a greater proportion of the rays from strontium-90 will penetrate into the marrow." It is quite possible that, for individuals prone to leukemia, strontium-90 poses hazards in addition to those that would be expected on the basis of criteria derived from experiences with radium.

To gain a clear understanding of the various kinds of radiation and their biological effects, it will be useful to review briefly some elementary concepts of atomic physics. Radioactivity is produced by changes that occur within the nucleus of an atom. These changes either directly or indirectly involve two nuclear particles, the neutron and the proton. The number of neutrons (electrically neutral particles) and protons (positively charged particles) in an atomic nucleus determines the species to which the atom belongs. Carbon-12 and carbon-13 for example, have six and seven neutrons, respectively, and are called isotopes of the element carbon. Every carbon

atom, however, has six protons in its nucleus and an equal number of external electrons (negatively charged particles), which can be thought of as "revolving" around the nucleus like planets in a miniature solar system. Similarly, all hydrogen atoms have one proton and one planetary electron, whereas hydrogen-2 and hydrogen-3 have one and two neutrons, respectively. When carbon and hydrogen combine to form hydrocarbons, the nuclear particles (protons and neutrons) of the two elements are not affected by the combination. The chemical reaction of carbon and hydrogen is determined by the arrangement of their planetary electrons. Each element can be separated from the other without any loss of its original identity and without producing ionizing radiation. On the other hand, if carbon were to gain or lose any protons, it would become an entirely different element. Gains or losses in the number of protons may occur when a neutron is converted into a proton, when a proton is converted into a neutron, and, of course, when a proton together with a neutron is emitted from the nucleus of an atom. These changes and the various energy adjustments that occur within the nucleus produce ionizing radiation.

The more familiar elements that make up the earth do not undergo nuclear changes spontaneously. Their nuclei are extremely stable. A few elements, however, such as uranium, radium, and polonium, have unstable nuclei. They emit particles and eventually break down into more stable elements. Radium, which is derived from the decay of uranium, disintegrates into radon by emitting two protons and two neutrons. Decay continues through a series of radioactive daughter products until the atom becomes lead. The two protons and two neutrons emitted by the radium atom remain together and constitute an alpha particle. Streams of these neutron-proton groups, or alpha "rays," are emitted from radium nuclei at velocities of about 44,000 miles per second. In addition, radium emits gamma rays, and several daughter products of the element emit beta rays. Beta rays are streams of electrons and positrons (the positive counterparts of electrons); they travel at varying speeds, sometimes approaching the speed of light (186,000 miles per second). Gamma rays are physically the same as X rays, the difference in name arising from the difference in the sources of emission. (X radiation is produced when a fast-moving, free electron collides violently with an atomic nucleus and loses part of its surrounding electric field. Unlike gamma radiation, however, X radiation does not involve any energy adjustments within atomic nuclei.)

It takes 1,600 years for half a given quantity of radium to disintegrate into radon. Another 1,600 years must pass before the remaining quantity of radium is halved again. As this process goes on indefinitely, always leaving a remainder to be halved each 1,600 years, some radium will remain for an immensely long period. By the same token, by adding radioactive substances to his environment, man increases the amount that will remain indefinitely, whether the half-life of an element is 5,900 years (carbon-14) or 28 years (strontium-90). Although man can create radioactive elements such as strontium-90, there is nothing he can do to reduce their radioactivity. Radiation continues undisturbed, and is diminished only with the passage of time.

What effects do alpha, beta, and gamma rays produce in living tissues? Although the long-range effects of low-level radiation on animals and man are very much in dispute, there seems to be little doubt about the harmful changes radiation produces in cells. Radiation particles have been compared to bullets tearing into an organism, but the damage they cause depends upon the number of particles that reach the tissues. The particles interact with many of the atoms that make up our cells, either causing electrons to leave their orbits (ionization) or exciting combinations of atoms (molecules) to a point where they break apart. The resulting damage may be minor and easily repaired; on the other hand, it may be serious and permanent. Irradiated germ

cells may one day give rise to harmful mutations, and irradiated body cells may take the first step toward the development of cancer. An individual exposed to large dosages of radiation may exhibit symptoms of "radiation sickness" - nausea, vomiting, loss of hair, progressive weakness, and hemorrhages. Severe irradiation of the entire body damages the blood-forming organs in man and higher animals, often claiming life within several weeks after exposure. If the whole body is exposed to very high levels of radiation, there will be widespread destruction of the intestinal tract and nerve cells. In such cases, death is certain to occur within a few days after exposure.

Quantities of radiation are usually expressed in terms of rads and roentgens. (These units are used in most of the works cited in this discussion. During the past few years, however, the rad has been steadily supplanted by the rem (roentgen equivalent man) in discussions of the effects of radiation on humans. The terms "rem" and "rad" signify identical values for exposure to beta and gamma radiation.)

A rad denotes the quantity of radiation an individual absorbs; a roentgen denotes the amount of radiation (ordinarily X radiation) to which he is exposed. For the purposes of this discussion, no significant distinction need be made between the two units. A single rad or roentgen can be thought of as giving rise to about 1,000 ionizations in a single cell. An individual normally receives a total dosage of 3 to 5 roentgens from natural background radiation during the first thirty years of his life. Background radiation comes from cosmic rays, radioactivity in rocks, and radioactive elements in food and water. It constitutes the radiation to which man has evidently adapted himself over long periods of biological evolution. Although background radiation will vary in amount from one locale to another, the absolute quantities involved are ordinarily very small. A man living at sea level usually absorbs about 30 millirads (30 thousandths of a rad) of cosmic radiation a year. A man living at 5,000 feet above sea level is likely to absorb about 70 millirads annually. An individual who moves from sea level to a height of 5,000 feet will thus raise his absorption of cosmic radiation by little more than a rad during a thirty-year period. A man who remains behind at sea level may well acquire more than that amount in certain parts of his body, by having a tooth X-rayed, for example. In fact, a series of dental X rays will supply his jaw and neck with a larger amount of radiation than they are likely to acquire from natural background sources in the greater part of a normal life span.

When X rays are used for diagnostic or therapeutic purposes, the good they do outweighs the harm. Diagnostic X rays are usually directed at limited areas of the body, a form of exposure that is far less hazardous than irradiation of the whole body. However, despite recent claims to the contrary, there is no conclusive evidence that small doses of radiation are harmless. Although some research workers have reported that very low levels of radiation (5 roentgens or less per week) increase longevity in animals, others working with similar doses of radiation have found that the life span is shortened. In the cases in which increases in longevity were reported, the last animals to die were generally non-irradiated control animals. If radiation had any "beneficial" effect, it was that it seemed to reduce the death rate of irradiated animals in early age groups, but the maximum life span of the animals was shortened. (In the opinion of Alex Comfort, one of England's foremost authorities on the aging process in animals and man, the increase in longevity produced by low-level radiation 'is due partly to the slight physiological stimulus arising from 'stress' and partly to the fact that radiation at these low levels does more harm to parasites of various kinds than to the animals infected with them. In any case, the life extension is seen only in animal colonies where the survival curve is suboptimal. Among animals that are well cared for, radiation, if it has any visible effect, shortens life.")



There seems to be very little ambiguity, however, about the genetic effects of radiation. All the facts at hand indicate that any increase in the amount of radiation received by a large population produces a rise in the occurrence of harmful mutations. Nor do we have to rely exclusively on experiments with animals to acquire statistically significant evidence to support this conclusion. A study made by John T. Gentry and his colleagues in the New York State Department of Health suggests that areas with relatively high concentrations of radioactive rock are correlated with a high incidence of congenitally malformed children - many, perhaps most, of whose defects are believed to be caused by defective genes. By working primarily with statistics compiled from a million and a quarter birth certificates in New York State (exclusive of New York City), Gentry found that the over-all incidence of congenital malformation amounted to 12.9 per 1,000 live births in areas of the state which seemed to have the least amount of geologic radioactivity. The incidence of congenital malformation for areas which seemed to have the highest amount of geologic radioactivity was 17.5 - a difference of nearly 40 per cent. New York State, it should be noted, is not particularly radioactive; field measurements of background radiation were found to lie mainly in the range of 2.1 to 3.2 roentgens per thirty-year period. Additional evidence that the rate of malformation is influenced by the radioactivity of the geologic environment appears in a preliminary nation-wide study by Jack Kratchman and Douglas Grahn, of the U. S. Atomic Energy Commission. By grouping county and state mortality data according to the geologic provinces of the United States, Kratchman and Grahn found that "mortality incidence from malformation may be higher in those geologic provinces... that contain major uranium ore deposits, uraniferous waters or helium concentrations."

These studies are a reminder that man is probably far more sensitive to radiation than has generally been supposed. Although the living matter that surrounds the nucleus of a cell can often absorb a great deal of radiation without being significantly harmed, the nucleus itself is highly vulnerable. Theodore T. Puck and his coworkers at the University of Colorado Medical Center have recently shown that visible damage can be inflicted on chromosomes (the strands in the nucleus of the cell that carry the genes) with as little as 20 to 25 roentgens. The genetic apparatus of an ordinary body cell "thus shows extraordinary sensitivity to radiation," Puck observes. "Calculation indicates that the ionization of not more than a few hundred atoms within or around the space occupied by the chromosome may be sufficient to produce a visible break. It seems probable that an even greater number of lesions may occur and remain invisible, either because they are submicroscopic or because they become resealed before they are expanded."

If radiation is increased to 50 roentgens, many cells soon lose the ability to reproduce, although they do not necessarily die. The nuclear material of the cell may be damaged beyond recovery, but the cytoplasm surrounding the nucleus survives and performs the essential functions of life. Instead of reproducing, the cells continue to absorb nutriment and grow until they reach enormous size. They become so-called "giant cells," seven to ten times larger than a cell that has not been irradiated. Irradiation of the whole body with 400 to 500 roentgens is fatal to half the human beings so exposed, apparently because over 99 per cent of the body's reproducing cells lose the ability to multiply normally. Individuals who receive lethal dosages of radiation may live for weeks after exposure, but the body's inability to form a sufficient number of red and white blood cells eventually leads to death from anemia or infection.

Children are probably more sensitive to radiation than adults, and the fetus appears to be more sensitive than the child. Radiation not only has a selective effect upon different parts of a cell; it does the greatest damage to those cells that have a high rate of reproduction. It seems to be

most harmful during those stages of life at which metabolism is at its peak, notably the years of growth. Sensitivity varies markedly from individual to individual and from one organ of the body to another. A large whole-body dose of radiation from which some individuals recover with a self-limiting case of "radiation sickness" may lead in others to permanent damage and death. If concentrated on the hand, the same dose may produce nothing more than a radiation burn. Directed at the abdominal area, however, it will often cause serious damage and marked physiological reactions.

Finally, there are different kinds of radiation and various emitters of radiation. The effects produced by all forms of radiation are ordinarily reducible to the amount of ionization they produce. But each form of radiation has distinctive features of its own. The alpha particle is the "heavy artillery shell" of ionizing radiation. As it is made up of two protons joined with two neutrons (actually a nucleus of the element helium), an alpha particle has about 7,300 times the mass of the lighter, faster beta particle. The penetrating power of alpha rays is very limited; they can be stopped by a thin sheet of paper. But although alpha particles do not penetrate very far into living tissue, they score a large number of "direct hits" on atoms. An irradiated cell is damaged more severely by alpha particles than by other forms of radiation, although fewer cells are irradiated by an alpha emitter. If the alpha particle had the penetrating power possessed by beta and gamma rays, it would be extremely destructive to living things.

Beta particles travel about 100 times farther than alpha particles. Whereas alpha particles seldom pass beyond the outer, dead layer of the skin, the free, fast-moving electrons and positrons that constitute beta radiation penetrate for about a quarter of an inch into living matter. Gamma rays and X rays will pass readily through a large organism; they reach the innermost recesses of the body and injure highly sensitive tissues, but they produce only about one twentieth of the damage inflicted on cells by alpha particles.

As gamma rays are physically the same as X rays, we might say that most of the effects produced in man by gamma radiation are due to the widespread use of X-ray equipment. Alpha and primary beta radiations are carried to man's vital organs by radioactive elements. (The word "primary" is used because beta radiation induces gamma radiation in much the same way that a stream of electrons striking a metal target produces X rays. Gamma radiation, in turn, by imparting energy to the planetary electrons of atoms, causes them to leave their orbits. The free electrons behave like a beta ray. Thus, a short-lived series of radiations, alternating between beta and gamma rays, could extend the range of biological damage to tissues that might not ordinarily be reached by the primary beta ray.) X-ray equipment can be turned on and off; thus, exposure to X radiation need not be continuous or uncontrolled. But radioactive isotopes cannot be "turned off." Once they combine with the skeleton and the soft tissues of the body, they are no longer within human control. Like the nutrients that sustain life and growth, many radioactive elements become part of the organism. The body tends to use radium and strontium-90, for example, the same way that it employs calcium, although it shows a preference for the latter. Radium and strontium-90 migrate to the mineral part of the skeleton, where the rate of metabolic activity is relatively low, and they bombard bone matter and highly sensitive bone marrow with alpha and beta particles for a long period of time. The body does not discriminate between radioactive and stable carbon isotopes. Carbon-14 appears in every kind of tissue, including germ cells, and irradiates the area in which it lodges with beta particles.

In the field of radiobiology, it is very imprudent to make ironclad generalizations that are likely to affect the well-being of large populations. The field is beset with so many uncertainties

that scientific opinion can be expected to differ on nearly every issue but the "need for further research." The public, in turn, would probably acknowledge this need with tranquility if the problems of radiation were confined to the laboratory. But they are not. X-ray machines are now part of the equipment of every physician and dentist; the devices have become indispensable in medical practice. Radioactive isotopes are used widely in laboratories, hospitals, and industry. Nuclear weapons tests have discharged radioactive debris into the soil, water, and atmosphere, and nuclear reactors are annually producing huge quantities of highly radioactive wastes. The experimental animals needed for further research currently include all of humanity, and the modern radiation laboratory encompasses the entire earth. But many serious questions have been left unanswered. Are we using radiation with the caution and respect it deserves? To what extent have we contaminated the environment? In what direction are we going? Unless these questions are answered frankly and existing abuses corrected, the data acquired by further research may well prove to be of academic importance.

## **The Problems of X Radiation**

X-rays were the first form of ionizing radiation to be deliberately produced by man, and in the United States and western Europe they now constitute the radiation to which he is most heavily exposed. Many people of all ages and all walks of life are given routine X rays during periodic medical and dental examinations. Moreover, exposure to X rays has been increasing steadily over the past three decades. According to data gathered by the National Advisory Committee on Radiation, the annual X-ray dosage received by the average American increased 900 per cent between 1925 and 1955. The radiation he receives from X rays is 135 per cent greater than the radiation he acquires from natural sources. "The continued upward trend exhibited by X-ray data," observes the committee, "suggests the likelihood that the current exposure of the population from X-ray apparatus may increase still further unless appropriate radiation control measures are systematically applied."

Systematic control of X radiation is long overdue. Man-induced radiation has been in use since 1896, the year Roentgen's discovery of X rays attracted world-wide attention, and the effective application of these rays to medical problems antedates World War I. Surprisingly, a good working knowledge of the hazards of X radiation and valuable recommendations for the proper use of X-ray equipment were available shortly after Roentgen's work became well known. Elihu Thomson, after experimenting with the new rays on his little finger, reported a great deal of the data needed to enable radiologists to use X-ray equipment with a reasonable amount of safety. His suggestions were largely ignored. For many years X-ray tubes were employed with little or no shielding, while physicians, in blissful disregard of Thomson's recommendations, often exposed themselves as well as their patients to heavy doses of radiation. By the early 1920's, scores of radiologists had needlessly sacrificed their lives and, in all probability, inflicted a great deal of damage on many of their unsuspecting patients.

To make matters worse, X-ray equipment was rapidly debased into a cosmetic agent and, finally, into a sales promotion device. It was found that X rays could cause a loss of hair (epilation), an effect that suggested lucrative possibilities. By the 1920's many physicians, beauticians, and self-appointed "epilation specialists" had begun to treat women with radiation for the removal of "superfluous hair." One New York physician, Dr. Albert C. Geyser, developed a "harmless" method

of hair removal that involved cumulative dosages of at least 500 roentgens over a twelve-week period of radiation treatment. The method, named the "Tricho System," was very successful, and beauticians trained by Geyser's "Tricho Institute" began operating in many parts of the United States and Canada. It soon became evident, however, that women treated according to the "Tricho System" lost substantially more than unwanted hair. Many individuals acquired radiodermatitis (skin inflammation), severe radiation burns, festering skin ulcers, and, in time, cancer. The "Tricho" story is one of the more tragic episodes in the history of radiation. It is believed that the victims of Geyser's system numbered in the thousands; the exact number of those who suffered latent injury and premature death will never be known.

Although radiation is no longer employed in the American beauty parlor, the use of X-ray equipment to fit shoes still lingers in a number of communities. The equipment is used mainly on the feet of children. As of 1960, the use of the shoe-fitting fluoroscope had been banned in twenty-nine states. Some of the other states regulate the use of the machine, but in a few states there are no restrictions at all. A number of local surveys cited by Schubert and Lapp have shown that the machines are often defective, giving high doses of radiation to both the child and the salesman. The Michigan Department of Health, for example, found shoe-fitting machines that emitted as many as 65 roentgens (r) a minute. A survey in Boston showed that irradiation of the foot ranged from 0.5 to 5.8 r a second. (The use of shoe-fitting fluoroscopes has been banned in Boston by state law and is regulated in Michigan.) "For a 22-second exposure, which is commonly used, the feet receive from 10 to 116 r!" Schubert and Lapp write. "Remember, too, that one child may have his feet examined many times while trying on different shoes. Similar dosage measurements have been reported by the United States Public Health Service, which states that the average dosages to the children's feet are between 7 r and 14 r per exposure." The amount of scattered radiation that reaches the child's pelvic region and gonads may run as high as 0.2 roentgens for a Twenty second exposure.

Society has found it very difficult to accept the fact that a valuable device can become extremely dangerous if it is used improperly. Schubert and Lapp observe that a major reason why Geyser was not stopped until his "system" had injured a large number of women is that the medical community generally accepted radiation as a form of treatment for minor skin disorders. To this day, many physicians are likely to underestimate the amount of latent damage caused by repeated exposure to X radiation. In some cases, physicians are inclined to use X-ray equipment as freely as they use the stethoscope, and often it is the cost of an X-ray picture rather than the 'risk of irradiation that keeps the two devices from occupying places of equal importance in routine medical examinations. The physician often feels that there is no danger involved in taking diagnostic X rays; the word "diagnostic" seems to impart benign qualities to radiation. But the need for an X ray does not in any way diminish the effect of exposure; it merely provides a scale on which the hazards of X radiation should be weighed against the hazards of an incomplete and faulty diagnosis.

This requires careful evaluation. A middle-aged man who refuses to be exposed to the small amount of radiation involved in an annual chest X ray carries his fear of radiation to extremes. The risk involved in having an X ray taken is much smaller than the risk involved in permitting a serious lung disease to remain undiagnosed. Schubert and Lapp estimate that sixty chest X rays taken on a 14-by-17-inch plate without accompanying fluoroscopies will give an individual a cumulative dose of 3 roentgens. With newly developed fast films, exposure is likely to be reduced appreciably. Similarly, a man with marked and prolonged gastrointestinal distress who fails to

respond to treatment for benign stomach disorders would be foolhardy if he refused to have X rays taken of his abdominal region. The danger of serious disease would outweigh by far the amount of harm caused by a single series of X rays.

But individuals without medical complaints who are exposed periodically to a large amount of diagnostic radiation might do well to entertain some second thoughts. For example, many large American corporations have established the practice of sending their executives to clinics for annual medical examinations. These examinations take several days to perform and normally include a program of X rays and fluoroscopies of important organs of the body. Schubert and Lapp found that an executive can expect to receive 35 roentgens with each checkup; frequently the dosages reach 50 roentgens. 'We grant that the executive is not exposed to total body radiation, which is more serious than localized radiation,' they write. 'Nevertheless, the most vital organs are exposed and at the very least one may expect a shortening of life span of the exposed individual, especially if the executive receives the x-ray bombardment year after year. We do not deny the valuable data which doctors may gain in the course of x-ray examination, which may lengthen the life span, but we do regard the annual irradiation of 50 r per executive with some degree of apprehension for the individual's future welfare.'

A number of radiobiologists believe that certain X rays should not be undertaken unless they are absolutely necessary for the well-being of the patient. A case in point is the pelvic X ray (pelvimetry) of pregnant women. 'X-ray pelvimetries have been a relatively common practice for many years - and still is as far as is known,' Schubert told a congressional committee holding hearings on radiation in 1959. An estimated 440,000 American women and 100,000 English women were given pelvic X rays annually during the late 1950's. The practice had always aroused a certain amount of concern because of the harmful genetic effects it could produce in later generations, but recent studies show that the hazards may be more immediate. In an extensive survey of deaths from cancer among English and Welsh children, Alice Stewart and her coworkers at Oxford University found a statistical relationship between fetal irradiation and the incidence of cancer among children. The survey, perhaps the most extensive of its kind, covered most of the children who had died of leukemia and other cancers between 1953 and 1955. The data gathered by the investigators show that, among children under ten, the chances of dying from cancer are twice as great for those who were irradiated during the fetal stage.

Moderate enlargement of the thymus gland, a condition for which a large number of children have received radiotherapy, is now regarded as harmless by many medical authorities. Although thymic enlargement is no longer treated with radiation in England, the practice still persists in the United States. C. Lenore Simpson and her coworkers have carefully surveyed about 2,000 such cases in New York State, mainly in Rochester and Buffalo. By comparing the incidence of cancer in treated cases with that in children in the general population, they found nearly a sevenfold increase in cancer among children who had been exposed to high dosages of radiation for thymic enlargement. The number of leukemia cases found by Simpson was nearly ten times higher than the number that would normally have been expected.

It remains to be seen whether most radiobiologists will decide that pelvimetries and thymic irradiation produce cancer in children. The evidence is not altogether clear-cut. Several later surveys of a more limited nature have reported findings that conflict with the results obtained by Stewart and Simpson, whereas other surveys support them. The results seem to vary with the methods used and the communities studied. The Stewart and Simpson surveys, however, have unearthed statistical probabilities that are far too high to be dismissed lightly. Although

these probabilities can be expected to vary with the techniques of the radiologists in different communities and medical institutions, there seems to be little reason to doubt the validity of the findings of Stewart and Simpson.

Physicians have observed that many children with thyroid cancer received radiation around the head and neck during infancy and early childhood. George Crile, of the Cleveland Clinic Foundation, for example, reports that in 18 cases treated by his clinic, the parents of 14 were asked whether their children had been exposed to X rays in the general area of the thyroid gland. Only 3 had not received radiation. The remaining 11 had histories of radiotherapy for enlargement of the thymus gland and lymph nodes, for eczema, and for other disorders. "In the 15 years between 1924 and 1939," Crile notes, "at a time when many more operations on the thyroid were being done at the Cleveland Clinic than are being done today, no children with cancers of the thyroid were seen. Only three were seen between 1939 and 1950, and between 1950 and 1958 there were 15 cases. The question immediately arises as to whether the increasing incidence of cancer of the thyroid in children is the result of an increase in the use of radiation therapy in infancy and early childhood." Crile notes that factors other than radiation may account for the rise in thyroid cancer among children but adds that "the increasing incidence of cancer of the thyroid in recent years suggests that an environmental factor such as radiation is involved."

Many individuals are still exposed to large dosages of X radiation for what are essentially cosmetic purposes. Localized eczemas, warts, and childhood birthmarks that are likely to disappear spontaneously after a few years have in many cases been heavily irradiated. This practice is declining owing to a greater awareness of radiation hazards, but it is still found too often to be overlooked.

Radiation, to be sure, is still the only effective method for treating certain irritating or disfiguring skin disorders, and the patient may be the first to demand radiotherapy in full awareness of the risk involved. Radiotherapy also reduces the severe pain that accompanies ankylosing spondylitis, an arthritic disease of the spine that afflicts thousands of men and often leads to a useless or impaired life. In such cases, where irritation or pain may be severe, it is unlikely that the hazards of radiation will deter a patient from accepting radiotherapy. He will probably take the risk - especially if the risk is relatively small. (In England the incidence of leukemia among men who have been treated with X radiation for ankylosing spondylitis "is about one third of one per cent; yet calculations based on the national death rates... show that even this low incidence is about ten times greater than would have been expected in the absence of irradiation.")

The element of risk cannot be avoided, but the amount of risk can be reduced appreciably. X-ray equipment can be used with moderation and with good sense. Doctors should be made thoroughly aware of the hazards involved and they should be taught the most advanced methods of reducing exposure. The physician should limit the use of his equipment to those aspects of radiology with which he is thoroughly familiar. A general practitioner is not a radiologist. Where complex techniques are required to diagnose a disease or treat a patient, the patient should have the benefit of the special training and experience that come from long service in the field of radiology. There is also an area which both layman and physician can enter with equal authority - that of radiation safety. Careful shielding from scattered X rays should always be provided for sensitive areas of the body, such as the gonads, neck, and abdominal region, particularly when children and young people are being irradiated. A patient has a right to insist upon protection whenever it is feasible, and in this he has the emphatic support of the most knowledgeable authorities in the field of radiology.

The use of X-ray equipment should be carefully regulated. These devices do not belong in the hands of quacks and shoe salesmen. Technicians should be licensed personnel who have given substantial evidence of their qualifications to operate X-ray equipment. Their work requires careful training that cannot be picked up through irregular, offhand instruction. There should be compulsory periodic inspections of X-ray equipment by competent agencies. Concerted efforts must be made to bring the latest advances in radiology into physicians' offices and hospitals. Research has produced faster films, electronic devices to increase the brightness of fluoroscopic screens (with concomitant reductions in X-ray dosage), image intensifiers, and improved filters that eliminate diagnostically useless long-wave radiation. Some of these improvements are too costly for the ordinary physician; hence the need to make use of the services of a well-equipped radiologist or hospital when a program irradiation is required. It is the responsibility of the community to see that outdated X-ray equipment is scrapped and that no one is exposed to defective and potentially harmful machines.

Unfortunately, the available evidence suggests that, in most cases, both the machines and the physicians' techniques are unsatisfactory. A recent two-year survey of diagnostic X-ray equipment in New York City, for example, showed that 92 per cent of 3623 machines inspected by the Board of Health either were not being used properly or were defective. The survey disclosed that X-ray beams were very broad, needlessly irradiating parts of the body that were not under study. The majority of physicians who were not radiologists were unfamiliar with the safety recommendations of the National Committee on Radiation Protection. The inspectors did not find a single physician who had voluntarily followed earlier recommendations to switch from outmoded to new equipment. Although the survey covered only 35 per cent of the machines employed in the city, it included the most frequently used X-ray machines, notably those in hospitals and in the offices of radiologists.

This survey, it should be emphasized, took place in 1959 and 1960 not a half century ago, when research on radiation was still in its infancy. The survey followed a period of widespread public discussion on the hazards of radiation and nuclear fallout. It is now clear that the situation is much worse than had generally been supposed. Exposure to radiation is occurring on a scale that has no precedent in man's natural history. Millions of people in all stages of life, from the fetal to the senile are being irradiated every year. Clearly the problem of radiation control has reached serious proportions. From the various reports "on the influence of ionizing radiation on biological systems," observes the National Advisory Committee on Radiation, "... it is evident that serious health problems may be created by undue exposure and that every practical means should be adopted to limit such exposure both to the individual and to the population at large."

## Fallout

X-ray equipment, we noted earlier, can be turned on and off, but the radioactive wastes that enter man's environment through nuclear weapons tests and the activity of nuclear reactors are essentially beyond human control. They contaminate air, water, and food, and they irradiate everyone, irrespective of age or health. Radioactive contaminants also create problems not encountered with conventional pollutants. Ordinary contaminants usually lose their toxic properties by undergoing chemical change, but there is no loss of radioactivity involved in the chemical reactions of radio-isotopes. When radiocarbon combines with oxygen to form carbon dioxide,

the carbon in the compound continues to emit beta particles. The same is true for chemical compounds formed by strontium-90. Radioactivity persists in all radio-isotopes until unstable atoms decay into stable ones.

Until recently, the layman was given a highly misleading picture of the hazards created by nuclear weapons tests. This picture was largely created by the Atomic Energy Commission, the official agency that had been made chiefly responsible for furnishing the public with information in the field of nuclear energy. For many years the A.E.C. consistently minimized the danger posed by radioactive fallout produced by nuclear weapons tests. For example, it completely ignored the extent to which food had been contaminated with strontium-90 until the problem was raised by scientists who were critical of the agency's public information policies. "In the 13th Semiannual Report of the AEC, published in 1953," notes Barry Commoner, of Washington University, "the AEC stated that the only possible hazard to humans from strontium-90 would arise from 'the ingestion of bone splinters which might be intermingled with muscle tissue during butchering and cutting of the meat.' No mention of milk was made" - or, for that matter, of vegetables and cereals. Spokesmen for the A.E.C. predicted that fallout would be uniformly distributed over the earth, so that no areas need fear concentrations of debris from nuclear weapons tests. The public was assured that the greater part of the debris sent into the stratosphere would remain aloft for a period of five to ten years. As fallout occurs very slowly, it was said, the radioactivity of short-lived radio-isotopes would be almost entirely dissipated in the stratosphere.

Actually, the radioactive debris that soars into the stratosphere stays there, on an average, less than five years. According to General Herbert B. Loper, of the Department of Defense, half the stratospheric debris produced by a nuclear explosion returns to the earth within two years. Fallout occurs three and one half times faster than Willard F. Libby, former commissioner of the A.E.C. had estimated. A model of stratospheric air circulation developed by A. W. Brewer and G. M. B. Dobson indicates that the heaviest fallout in the Northern Hemisphere occurs in the temperate zone, reaching a peak between 40 and 50 degrees north latitude - or roughly between Madrid and London in Europe and between New York City and Winnipeg in North America. Measurements made during the 1958-61 nuclear weapons test moratorium indicate that the hazard from fallout in these latitudes is substantially greater than the world-wide average. (Let us grant that the A.E.C. had made an honest error, but how did the agency handle the facts when it became evident from classified data that its predictions were wrong? A chronological account prepared by the Joint Committee on Atomic Energy indicates that a restudy by the A.E.C., released early in 1959, "makes no mention of [the] Defense Department study" and "maintains [the] position of a residence time of 5 to 10 years, selecting 6 years as the mean residence time of stratospheric fallout. Results of another AEC analysis, Project Ash Can, which indicated a residence time of 3 years, was discounted as being doubtful. No mention was made that the Department of Defense conclusions of residence half life of 2 years tended to support results of Project Ash Can.")

The rapidity with which radioactive debris descends to the earth places the danger presented by short-lived, supposedly harmless radioactive elements in a new perspective. Cesium-144 and strontium-89 have half-lives of only 290 and 56 days, respectively, but nuclear explosions produce these radioactive elements in such relatively large quantities that, if fallout is rapid, they become a serious hazard to public health. Cesium-144, like long-lived cesium-137 (another component of fallout), is an emitter of beta rays. When taken into the body, both cesium isotopes are handled metabolically like potassium; they migrate to all the soft tissues, including the reproductive organs. Strontium-89 possesses the characteristics of strontium-90; it, too, emits beta rays and



tends to lodge in bone matter. Although a short-lived bone seeker like strontium-89 might seem to be relatively harmless, it should not be underestimated as a hazard to public health. "Since strontium-89 is produced more abundantly in fission than strontium-90..." the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy reported in 1959, "it is possible that comparable doses to the body from the two materials could occur." The subcommittee added that "it would require 100 times more initial activity of strontium-89, whose half life is 56 days, to deliver the same dose to tissue that would be created by 1 unit of strontium-90. It is considered significant that transient levels of strontium-89 with approximately this ratio to strontium-90 have been observed in milk."

For a few weeks after a nuclear explosion, the wind-borne debris in the lower part of the atmosphere may contain appreciable amounts of iodine-131. Iodine-131 has a half-life of eight days. At the 1959 hearings of the Special Subcommittee on Radiation, E. B. Lewis, of the California Institute of Technology, observed that "the radioiodines in fallout are a special hazard to infants and children. This hazard arises for a variety of reasons. Radioiodine is a significant fraction of the fresh fission products released by nuclear weapons explosions. Grazing cattle ingest and inhale the radioiodines in fallout and then concentrate it in their milk. Infants and children are expected to ingest more of the isotope than will adults since fresh cow's milk is the principal source of fallout radioiodine in the human diet and young people obviously drink more fresh milk than do adults. As has long been known, iodine isotopes, natural and radioactive, concentrate in the thyroid gland. Moreover, for the same amount of radioiodine orally ingested, the infant thyroid receives some 15 to 20 times the dose that the adult thyroid receives. (Briefly, this is because more radioiodine is taken up by the infant than by the adult thyroid; as a result many more of the short-ranged iodine-131 beta rays will be generated in a gram of infant than in a gram of adult thyroid tissue.) Finally, in spite of its small size, the infant thyroid may be more susceptible than the adult thyroid to cancer induction by ionizing radiation."

No one denies that radio-isotopes produce damage when they are deposited in the human body. Controversy tends to center around the "maximum permissible concentrations" (MPC's) that have been established for the quantities of various radioactive elements that the human body can be allowed to accumulate. (In the United States, the term "maximum permissible concentration" is being superseded by "radiation protection guide" (RPG), and the job of formulating "acceptable" values of exposure to radiation has been placed in the hands of the newly formed Federal Radiation Council. These changes, however, do not affect the substance of the discussion that follows.) There is nothing safe about an MPC. An MPC constitutes the amount of risk an official agency is prepared to inflict upon certain individuals and the general population in carrying out a nuclear-energy program. The U. S. Naval Radiological Laboratory points out that any degree of exposure to ionizing radiation produces "biological effects." "Since we don't know that these effects can be completely recovered from," observes the laboratory's report to the Special Subcommittee on Radiation, "we have to fall back on an arbitrary decision about how much we will put up with; i.e., what is 'acceptable' or permissible - not a scientific finding, but an administrative decision."

Many scientists take a grim view of the "administrative decisions" that have established the permissible levels of strontium-90 for the general population. The MPC for strontium-90 is measured in strontium units (S.U.), formerly called "sunshine units." A single S.U. is one micromicrocurie ( $\mu\mu\text{c}$ ) of strontium-90 per gram of calcium (a  $\mu\mu\text{c}$  is equal to one millionth of a millionth of a curie; a curie essentially represents the amount of radioactivity associated with one gram of radium).

For a number of years, the maximum permissible concentration for strontium-90 was established by a definite although largely unofficial procedure. The MPC originated as a recommendation by the International Commission on Radiological Protection (I.C.R.P.), an advisory body made up of scientists from all parts of the world. The International Commission's recommendation, in turn, was usually adopted by the National Committee on Radiation Protection (N.C.R.P.), the American affiliate of the I.C.R.P. Finally, the National Committee's recommendation was generally adopted by government agencies.

Until 1955, the recommendation of the International Commission dealt almost exclusively with problems of occupational exposure to radiation and radioactive isotopes. The problem of formulating an MPC for the general population was left in the hands of the commission's national affiliates and official agencies. This created a highly unsatisfactory situation. It made it possible for official agencies to grossly understate the hazards of nuclear weapons tests; they proceeded to evaluate all the dangers that fallout presented to the general population in terms of the large MPC established for workers in atomic plants. "The maximum permissible level of strontium-90 in the human skeleton, accepted by the International Commission on Radiological Protection, corresponds to 1,000 micromicrocuries per gram of calcium [1,000 S.U.]," noted the British Medical Research Council in the mid-1950's. "But this is the maximum permissible level for adults in special occupations and is not suitable for application to the population as a whole or to children with their greater sensitivity to radiation and greater expectation of life." To cope with this problem, the International Commission decided in 1955 that the prolonged exposure of a large population to radiation should not exceed one tenth of the maximum permissible levels adopted for occupational exposures. For all practical purposes, the commission's recommendation meant that the MPC for strontium-90 established for the general population should be reduced from 1,000 to 100 S.U.

It was not until a great deal of controversy had developed over the established MPC for strontium-90 that the National Committee, followed with undisguised reluctance by the A.E.C., adopted the "one-tenth rule" recommended by the International Commission. It soon became evident that even this 90 per cent reduction was inadequate. Finally, the International Commission made a curious, perhaps contradictory decision: It raised the MPC for workers in atomic plants from 1,000 to 2,000 S.U. but recommended that the MPC for the general population be reduced to one thirtieth of the occupational level. Thus, in a circuitous, often confusing manner, the permissible level of strontium-90 for the general population has been reduced to 67 S.U., or one fifteenth of the MPC (1,000 S.U.) that was in effect in 1954.

The problem of establishing a "suitable" MPC, however, is still unsettled. Strontium-90 is not uniformly distributed in bone matter. The element, like radium, tends to form "hot spots," some of which may exceed the average skeletal distribution many times over. To estimate the damage which skeletal concentrations of strontium-90 are likely to produce, a factor,  $N$ , should be used to increase any average result based on a uniform distribution of the element in the bone especially in the case of adults, who form these "hot spots" more readily than children. Two Swedish investigators, A. Engstrom and R. Bjornerstedt, who have pioneered in research on this problem, emphasize that  $N$  is not constant. The factor may vary from 6 to 60, depending upon individual metabolism and variations in the amount of strontium-90 that appear in food, air, and water. An individual who acquired an average, presumably "safe," skeletal burden of 65 S.U., for example, might well have minute "hot spots" of nearly 4,000 S.U.-enough to increase appreciably his chances of developing cancer.

"Meanwhile, what is the course of wisdom?" asks W. O. Caster, of the University of Minnesota. "Some claim that where there is honest doubt, public safety demands that the safety standards be adjusted to cover the worst possible contingency. But if one couples Dr. Engstrom's estimate of 100 strontium units as the maximum permissible level for radiation workers with the International Commission's suggestion that the permissible level for a population should be one thirtieth the occupational level, it would appear that the population limit should be only three strontium units. Some children have already passed this mark. The official agencies point out that, in the absence of proof that such a level is in any way deleterious, it would be the height of irresponsibility to raise a public alarm." The proof required by official agencies, however, might not be forthcoming for ten or fifteen years.

Whatever the analytic method employed, there is no doubt that concentrations of strontium-90 in human bones have been rising steadily over the past decade. The principal source of American data on the amount of radio-strontium entering the human body is an A.E.C. financed research project at the Lamont Geological Observatory of Columbia University under the direction of J. Laurence Kulp. Thus far, Kulp's research group has issued four reports, covering the years 1954-9. The data show that for the 'Western culture' area (Europe and the United States), situated between 30 and 70 degrees north latitude, the average amount of skeletal strontium-90 in adults increased from 0.07 S.U. in 1954 to 0.31 S.U. in 1959. The amount of radio-strontium in the bones of children up to four years of age rose from 0.5 S.U. in 1955 to 2.3 S.U. in 1959, a total seven times the amount in adults. Although the body discriminates in favor of dietary calcium against strontium, the discriminatory factor varies with age. As adults no longer undergo skeletal growth, they add only about one fourth of the strontium they ingest to their bones; children, however, add about half.

The value of averaging the amount of strontium-90 in bones at a given collection point, and then averaging the averages for an entire "culture area," is highly questionable. Jack Schubert has pointed out that "when dealing with a potentially harmful agent involving the world's population, it can be misleading to use average values of strontium-90 in the bones. It is important, especially in relation to the setting of permissible levels for a world population, that we have some basis for estimating the degree to which appreciable fractions of the population accumulate two and more times the average amount." Using more suitable mathematical methods than those employed by Kulp and his colleagues, Schubert shows that 28.8 per cent of the skeletal specimens analyzed in the 1957-8 Kulp report "have three or more times the average (geometric mean) amount of strontium-90 in their bones. Over 4 per cent will have seven or more times the average. These values are appreciably greater than those of Kulp's who used incorrect averages and an incorrect distribution curve and hence underestimated the fraction of the population which would exceed the average values." (For the benefit of readers who are familiar with statistical methods, it might be added that a proper evaluation of Kulp's data requires a Poisson distribution, not the normal distribution employed by Kulp and his group.)

Submerged in the avalanche of averages, estimates, and statistical extrapolations are those communities that have been heavily irradiated by fallout debris. "Substantial areas in Nevada and Utah close to the bomb testing grounds had received ten roentgens of gamma radiation as early as 1955," Caster observes. "Some 40 communities had had average doses between one and eight roentgen units. Such doses are substantially above allowable levels for the general population - or for professional personnel for that matter." In May 1953, for example, a sudden change in weather caused the fallout "cloud" from a Nevada test series to move over well-traveled and

inhabited areas near Yucca Flats. According to an account of the episode by Paul Jacobs, fairly high levels of air contamination were recorded in St. George (population 5,000) and Hurricane (population, 1,375). (A similar incident occurred a year later, when a large group of Marshall Islanders received high doses of radiation as a result of a hydrogen-bomb test at the A.E.C.'s Eniwetok Proving Grounds in the Pacific Ocean. Exposure to fallout was sufficiently high to induce symptoms of "radiation sickness" in many of the natives. Had the wind veered thirty miles to the south, the entire population of the islands would have been exposed to lethal doses of radiation (about 1,000 roentgens). Hundreds of motor vehicles traveling the highways near the test site required decontamination, while residents of endangered communities (when they could be reached) were warned to remain indoors. At St. George, reports Jacobs, a "high degree of contamination continued for sixteen days after the shots."

Radioactive debris from the Nevada test explosions normally drifts in a northeasterly direction toward the grain and dairy states of the upper Midwest. It tends to settle out in areas where a large percentage of the American food supply is raised. As a result, high concentrations of strontium-90 have been found in food plants, especially cereals, grown in many parts of the Great Plains region. In 1957, for example, wheat samples collected from seven agricultural experiment stations in Minnesota registered concentrations of strontium-90 about 100 per cent higher than the current daily maximum permissible level (MPL) for humans over a lifetime. The largest number of S.U. found in one group of Minnesota samples was 200 per cent greater than the MPL.

Had a moratorium on nuclear weapons tests not been established in the autumn of 1958, the amount of strontium-90 in milk from certain collection points in the United States might well have approached or equaled the current MPL value of 33  $\mu\text{c}$  per liter. The A.E.C.'s "Hardtack" series of explosions in Nevada and high-yield Russian tests in Siberia, both conducted during 1958, resulted in heavy fallout. In 1959, the amount of strontium-90 in milk reached 14.6  $\mu\text{c}$  per liter in New York City (July 18), 18.2 in Cincinnati, Ohio (May 19), 22.6 in Spokane, Washington (May 5), and 22.8 in Atlanta, Georgia (May 5). Heavy concentrations of strontium-90 appeared in wheat and cereal products, particularly in whole-wheat bread. During February 1959, for example, the levels of strontium-90 in whole-wheat bread obtained by the A.E.C. from New York City retail markets generally exceeded the MPL value of 33  $\mu\text{c}$  per kilogram. (With the resumption of nuclear weapons tests, the amount of strontium-90 in food is expected to reach unprecedented levels. It is likely that the strontium-90 in the milk supply of a number of American communities will substantially exceed the MPL of 33  $\mu\text{c}$  per liter. Estimates based on the Federal Radiation Council "radiation protection guides" (RPG's) place 1962 levels of strontium-90 in milk in the lower part of "Range II" (from 20 to 200  $\mu\text{c}$  of strontium-90 per liter). This range requires "active surveillance and routine control" by public health authorities. It is hardly necessary to emphasize that there will be a sharp increase in skeletal burdens of strontium-90, especially in children and young adults.)

Attempts have been made by highly responsible scientists to estimate the damage caused by the fallout debris produced to date. According to A. N. Sturtevant, professor of genetics at the California Institute of Technology, fallout will produce harmful genetic mutations in 4,000 people in the first generation and in 40,000 people in generations to come. Although these figures represent Sturtevant's latest published estimates (1959) they are calculated on the basis of the radioactive debris produced up to 1956. Since then, the total amount of fallout has increased about 70 per cent. On the basis of more up-to-date material. James Crow, president of the Genetics Society of America, estimates that 20,000 mutations will be inherited by the next generation as a

result of fallout (his estimate is based on the assumption that the present world population will produce a total of two billion children). The number would reach 200,000 if nuclear testing were resumed and continued for thirty years at the 1954-8 rate.

If E. B. Lewis's 'linear hypothesis' is correct, fallout may have contributed to the rising incidence of leukemia. According to Lewis's theory, the chances of acquiring leukemia increase in direct (or linear) proportion to increased irradiation. The hypothesis 'predicts that constant exposure to even one sunshine unit [strontium unit] would be capable of producing about 5 to 10 cases of leukemia annually in the United States population.' There seem to be very few scientists who deny that linearity exists in the middle dose range of radiation, but a great deal of controversy has arisen over Lewis's hypothesis that linearity exists at all levels of radiation, including the very low dose range involved in diagnostic X-rays and fallout. Yet there is a substantial amount of data to support his theory. Aside from the basic evidence that Lewis presented when his views were first published (1957), the linear hypothesis has gained strong support from the work of Alice Stewart and others on cancer in children (see page 170). The pelvimetries studied by Stewart and her coworkers involved dosages of only 2 to 10 rads; nevertheless, this low level of whole-body radiation directed at the fetus was enough to double its chances of acquiring cancer.

If Lewis's hypothesis is also valid for other forms of radiation-induced cancer, fallout from nuclear weapons tests may be responsible for thousands of cases of bone cancer. By using a statistical approach developed by the British Atomic Scientists Association, it is possible to make a rough but reasonable estimate of the number of such cancers that would be produced by increases in the amount of strontium-90 in human bones. A long-term average of only one strontium unit in the bones of every individual in the world may well cause 12,500 cases of bone cancer; as little as two strontium units may result in 25,000 cases. The figure increases proportionately as strontium-90 becomes part of the human skeleton. It is sobering to note that if the world population were to acquire an average skeletal concentration of 20 strontium units-or one third of the current maximum permissible concentration - a quarter of a million people might be afflicted with bone cancer.

All of these estimates and hypotheses may be wrong, but thus far there are no convincing reasons for believing that they err on the side of pessimism. "The byproducts of atomic fission are highly destructive to protoplasm," observe Ralph and Mildred Buchsbaum, "and in unique ways which present problems that were never posed by the other hazards man has introduced into his environment by his technology. The dangers are at present underestimated, rather than exaggerated, in the opinion of most biologists."

## The Nuclear Age

If nuclear weapons tests were ended permanently, we would still be confronted with far-reaching dangers created by the peacetime uses of nuclear energy. In contrast to the minuscule quantity of radioactive substances to which man had access before 1940, the nuclear-energy industry produces millions of curies of waste materials every year. The "high-level" wastes created by the reprocessing of partially spent nuclear fuels may contain as much as several thousand curies of radioactive substances per gallon. More than 65 million gallons of these lethal materials are stored in giant underground tanks at three locations in the United States. So-called "intermediate" and "low-level" wastes are discharged directly into the ground. Radioactive substances

in liquid form, for example, are piped into gravel-filled trenches and allowed to percolate into the soil. Over 2 1/2 million curies of solid and liquid waste products have been disposed of in the ground. The liquid wastes "work their way slowly into ground water," observes the A.E.C. in its 1959 Annual Report, "leaving all or part of their radioactivity held either chemically or physically in the soil." To put the key thought in this statement less obliquely: Part of the radioactivity reaches the ground water and passes into man's environment.

Large quantities of 'low-level' wastes have been discharged into rivers. At Hanford, Washington, for example, about 2,000 curies of substances that have been made radioactive by neutrons in reactors are released daily into the Columbia River. After making a survey of the Priest Rapids - Paterson section of the river, a group of U. S. Public Health Service investigators pointed out that "values as high as  $2.2 \times 10^{-3} \mu\text{c/gm}$ . [.002 microcuries per gram] have been found in the muscle of white fish near Priest Rapids." The writers reported that other river organisms "had gross beta activity densities considerably higher than adult fish, but these organisms are not utilized to any extent by humans. Thus, their major significance is in transmitting this activity to other organisms in the food chain. Fish as well as ducks, geese and other animals, may consume these organisms." These higher animals, it should be noted, are consumed by man.

In addition to using rivers as a means of disposal, the A.E.C. has dumped 65,000 concrete-lined drums containing 'low-level' radioactive garbage into the Atlantic and Pacific oceans. Owing to the corrosive action of sea water, the porosity of the concrete liners, and the high water pressures at the floor of the ocean, the drums may last as little as ten years. Approximately 60,000 curies of radioactivity were disposed of in the oceans before the A.E.C., yielding to widespread public protest, declared a "moratorium" on this type of disposal in all Atlantic and many Pacific coastal waters pending a further study of how effectively the wastes are retained by their containers. The A.E.C., however, is by no means the worst contributor to radioactive pollution of the oceans. British authorities allow their Windscale installations to pump as much as 10,000 curies of short-lived radio-isotopes into the Irish Sea every month.

What happens to these wastes when they enter the environment of fresh- and salt-water marine life? Generally, ecological factors play a number of ugly tricks on man; it has been clearly established that radioactive materials in water tend to be concentrated by plankton, algae, mollusks, and fish. "Available substances are rapidly taken up by the biota, never remaining long in the water to be diluted and washed away," observes Lauren R. Donaldson, of the University of Washington. "This is dramatically demonstrated following an atomic test in which radioactive materials are deposited in the water. Within hours, the great bulk of these materials is to be found in the living organisms. Plankton and some of the algae, which are the key organisms in the food chain, may concentrate within themselves more than a thousand times the amount of radioactive substances found in the sea water. The herbivorous fish and invertebrates have lower concentrations of radionuclides at any given time than do the plants on which they feed, and progressing along the food chain to the carnivores the concentrations become lower and lower."

There have been cases, however, in which the concentration of radioactive elements was higher in fish and mollusks than in plants. In a study of fallout on a four-acre pond near Cincinnati, L. R. Setter and A. S. Goldin, of the U. S. Public Health Service, found extreme variations in the concentration of radioactive isotopes among different species of water life. In some algae the amount of radioactivity was only 20 times greater than that in the water, but bass had from 300 to 400 times more, and snails from 1,000 to 3,000. Data supplied by Richard F. Foster, of the Hanford Laboratories, indicate that whereas algae in the Columbia River concentrate radiocesium

by a factor of 1,000 to 5,000, fish concentrate the element by a factor of 5,000 to 10,000. (Foster's report, incidentally, shows that algae can concentrate radio-potassium in amounts as much as a million times greater than that in river water, and fish can concentrate strontium-90 as much as a thousand times.) In any case, as one organism is nourished by another, the radio-isotopes reappear to a greater or lesser degree in the bodies of higher species. The route may be direct and simple or long and complex, but eventually a portion of the radioactive garbage finds its way back to man.

It is rather alarming to speculate on the direction the nuclear age may yet take. According to the Committee on the Effects of Atomic Radiation on Oceanography and Fisheries of the National Academy of Sciences, "300 nuclear powered ships of all nations will be in service by 1975. These ships could then potentially release to the marine environment approximately 5,000 curies per year from expansion water, some 3400 curies per year from leakage, and some  $9 \times 10$  to the fifth power [900,000] curies per year from the ion exchange beds." The total: 908,400 curies per year. At the same time, new reactors on the land can be expected to create ever-mounting problems of waste disposal. It has been estimated that if nuclear power furnished 10 per cent of America's current electrical output (a distinct possibility in the next few decades), there would exist in the world about 150 billion curies of radioactive isotopes from this source alone, including 2.6 billion curies of strontium-90 and 2.3 billion curies of cesium-137. These figures, let it be noted, do not include radioactive wastes that would be produced by nuclear power plants in other countries. Methods for the permanent disposal of such highly lethal materials would have to be "foolproof." If any miscalculations were made and the wastes began to seep uncontrollably into man's environment, they would cause a staggering amount of damage.

The nuclear age could have profound and far-reaching effects upon existing ecological patterns. Until recently, biologists assumed that the sensitivity of living things to radiation increases with the level of their evolutionary complexity. For example, viruses absorb between 50,000 and 100,000 roentgens before half or more of their number are killed; spore-forming bacteria, between 20,000 and 50,000; the weevil, between 1,000 and 2,000 roentgens. But mammals such as the dog, the goat, and man begin to succumb to whole-body doses of less than 500 roentgens. In reviewing the striking differences in radio-resistance between lower and higher forms of life, many biologists concluded that if man and other mammals could be protected from radiation, the rest of the biosphere would more or less take care of itself.

It seems unlikely, however, that this conclusion is correct. There appear to be critical periods in the development of many highly radio-resistant species during which they can be damaged or killed by fairly low levels of radiation. For example, it requires only 160 roentgens to kill half the eggs of the fruit fly during the early stages of cell division, whereas 100,000 roentgens are needed to achieve the same result with adults. The organism is 600 times more radio-resistant at one stage of its development than at another. As plants and lower animals tend to concentrate relatively large quantities of radioactive isotopes in their cells, a level of environmental contamination "harmless" to man may prove to be very harmful to less-developed species. The use of the soil, atmosphere, and bodies of water as dumping grounds for nuclear wastes could result in serious ecological imbalances that would eventually affect man. "When radioactive isotopes are released into the environment," observes K. Z. Morgan, of the Oak Ridge Laboratory, "they usually enter into complex physical and biological cycles and into food chains and may exhibit unexpected movements or concentrations. It is through such mechanisms that dangerous long-lived radionuclides such as strontium-90 and cesium-137 are able to enter our food sources. These

ecological food chains are actually circular in nature or web-like and have a limited number of links. Serious consequences would follow if too many of these food links were broken.”

Morgan emphasizes that the damage can be very subtle. Radiation may reduce the mobility of an animal or impair its sensory organs, such as the eyes. It may reduce the organism’s fertility. ”Also, if a small dose has any effect at all at any stage in the life cycle of an organism, then chronic radiation at this level can be more damaging than a single massive dose which comes at a time when only resistant stages are present. Finally stress and changes in mutation rates may be produced even when there is no immediately obvious effect on survival of irradiated individuals.”

Nuclear energy is associated with such huge problems in human affairs that the subtle dangers it creates for the biosphere may seem to be negligible. The tendency to deal with the atom in terms of massive destruction and large-scale economic exploitation may lower our guard and lead to serious ecological disturbances. Although the wastes discharged into the environment contain, for the most part, short-lived radio-isotopes, the daily volume of effluent is immense and the flow continuous. The radio-isotopes are picked up, concentrated, and circulated in increasing amounts by key organisms in the vicinity of nuclear reactors and processing establishments until many plants and animals become heavily contaminated. The smaller number of long-lived radioisotopes are carried further into major food chains that involve millions of people. Before creating new centers of radioactivity and adding to existing problems of waste disposal, we would do wisely to ask whether all the hazards of exposure to low-level radiation have been explored and whether all the alternatives to nuclear power have been exhausted. ”It is not too late at this point for us to reconsider old decisions and make new ones,” observes Walter Schneir in an excellent article on radioactive wastes. ”For the moment at least, a choice is available.”



# CHAPTER SEVEN: HUMAN ECOLOGY

## Survival and Health

Despite mounting problems and difficulties, most official statements on environmental change tend to be reassuring and optimistic. We are told repeatedly, for example, that the amount of strontium-90 in a quart of milk or the quantity of DDT in a fruit is "trivial"; that in order to ingest harmful doses of a radioactive element or a pesticide residue, an individual would have to consume enormous quantities of a contaminated food at a single sitting. These piecemeal explanations are little more than subterfuges. Many toxicants appear in all the fruits and vegetables we consume; in fact, strontium-90 and DDT are in almost every food in the modern diet. We ingest these substances daily with nearly every glass and spoon we raise to our lips. They appear in the air we breathe and the water we drink. Since the 1940's, strontium-90 and DDT have become an integral part of man's environment; the toxicants are almost as widespread as bacteria and dust particles.

An overall view of our synthetic environment, even if cursory and superficial, reveals a picture worse than that disclosed by the most exhaustive specialized investigations. Foods are sprayed not only with DDT but with a large assortment of inorganic and organic insecticides; they contain not only strontium-90 but additional radioisotopes created by man. A large part of the modern diet consists of highly processed foods to which questionable artificial materials have been added. Although the average man is engaging in less and less physical activity, his intake of carbohydrates and fats is very high. The growth of urban centers has been accompanied by increasing air and water pollution. The anxieties and tensions of modern life promote the consumption of cigarettes, drugs and analgesics. Modern man ingests an appalling variety of toxic materials every day, many of which are additive or interact in the body to produce a synergistic effect. (Two widely used organophosphorus insecticides, EPN and malathion, for example, are known synergists; each is toxic when ingested singly, but when they are taken together, EPN inhibits the hydrolyzing enzyme that detoxifies malathion, thus producing a toxic effect that is more than additive. Ionizing radiation, to cite another example, is not only carcinogenogenic in its own right, but also reinforces the activity of chemical carcinogens in tobacco smoke. As John W. Berg, associate editor of *Cancer*, notes: "...what we gain with cigarette filters we probable lose to fallout from atomic explosions.") The initial damage created by these toxicants is likely to be disregarded, partly because the more immediate symptoms of low-level, chronic poisoning, such as persistent fatigue and continual sense of ill-being, are so common that they are no longer taken seriously.

How does this conclusion compare with evidence that human longevity has been increasing? Actually, the claim that man is living longer today than he did a half century ago requires qualification. "It is important to realize that most of the gains in longevity have come about through prevention of mortality at young ages," observes James M. Hundley, of the National Institute of Health. "Great progress has been made in this sector. Relatively little has been gained in older age groups." Since 1900 about 19 years have been added to the life expectancy of newly born

white male children. A white male born at the turn of the century had a life expectancy at birth of 48.2 years; by 1958, newly born white males had a life expectancy of 67.2 years. But the gain diminishes sharply after the second decade of life and virtually disappears after the sixth. A man who is 20 years of age can expect to live 7.8 years longer than his counterpart in 1900; a man of 45 years of age, only 2.9 years; a man 65 years of age, merely 1.2 years. A child today has a better chance of reaching the age of 40, but after that his life expectancy is not appreciably greater than what it would have been at the turn of the century.

Moreover, it should not be forgotten that in 1900 millions of Americans lived in an environment in which survival was almost miraculous by present-day standards. The majority of urban dwellers lived in slums with a minimum of sanitation and medical care. A large number of children worked in factories. Their parents were shackled to a grim industrial routine for ten or twelve hours a day in patently unhealthful surroundings. Almost any improvement in social conditions or medical techniques would have rescued large numbers of people from premature death and added substantially to their life span. Today, sanitation, housing, working conditions, and income have been improved greatly, while medicine and scaled undreamed-of heights. Nevertheless, most of the increase in longevity is due to the fact that more children survive the diseases of infancy and adolescence today than two generations ago. What this means, in effect, is that if it weren't for the extraordinary medical advances and great improvements in the material conditions of life, today's adult might well have a much shorter life span than his grandparents had. This is a remarkable indication of failure. It suggests that modern man would find it very difficult to survive outside a medical and pharmaceutical hothouse.

What does life in a medical and pharmaceutical hot house entail? The answer, in cold statistics, is shocking. Nearly 41 percent of the American people have some form of chronic illness. ("About 40.9 per cent of persons living in the United States were reported to have one or more chronic conditions," reports the U. S. Public Health Service. "While some of these conditions were relatively minor, others were serious conditions such as heart disease, diabetes, or mental illness." Ten per cent of the American population are forced to limit their activity because of chronic conditions.) Many of these individuals are confined to wheel chairs, nursing homes, and hospital beds, faced with lifelong pain and inactivity. The statistics include numerous victims of heart disease, whose existence is marred by continual apprehension and fear. They include hundreds of thousands of cancer victims, a large percentage all but departed from the pale of the living. Worse still, however, the likelihood exists that the hothouse will begin to fall apart as the pace of chemicalization, urbanization, and pollution is increased. We have yet to feel the full burden of disease slowly being created by nuclear weapons tests, motorcar exhausts, and the newer chemical additives in our food. We are exchanging health for mere survival. We have begun to measure man's biological achievements, not in terms of his ability to live a vigorous, physically untroubled life, but in terms of his ability to preserve his mere existence in an increasingly distorted environment. Today, survival often entails ill health and rapid physical degeneration. We are prepared to accept the fact that a relatively young individual will suffer from frequent headaches and digestive disturbances, continual nervous tension, insomnia, a persistent "cigarette cough," a mouthful of decaying teeth, and respiratory ailments every winter. We expect his physique to acquire the rotundity of a barrel shortly after the onset of middle age; we find nothing extraordinary in the fact that he is incapable of running more than a few yards without suffering loss of breath or walking a few miles without suffering exhaustion.

What, then, is health? At the very least, health must be regarded as the absence of all the persistent pains, aches, tensions, and physical disturbances now accepted as a "normal" part of life. A healthy body is not a burden; it does not provoke an irritating awareness of its presence without reason. When we are in good health, we sense that our bodies are completely at our command, that they are in the service of our purposes and desires. Normally the "sound body lives in silence," observes Alexis Carrel. "We do not hear, we do not feel, its working. The rhythms of our existence are expressed by cenesthetic impressions which, like the soft whirring of a sixteen-cylinder motor, fill the depths of our consciousness when we are in silence and meditation. The harmony of organic functions gives us a feeling of peace."

This is, of course, a minimum definition of health - a definition that might be taken for granted if it were not for the fact that, as Carrel adds, many people, "although they are not ill, are not in good health. Perhaps the quality of some of their tissues is defective. The secretions of such gland, or such mucosa, may be insufficient or too abundant. The excitability of their nervous system, exaggerated. Their organic functions, not exactly correlated in space or in time. Or their tissues, not as capable of resisting infections as they should be." Carrel is obviously concerned with complex, interacting biochemical factors that are often difficult to pinpoint and measure in the laboratory. Nevertheless, many individuals whose response to conventional diagnostic tests indicates that they are "normal" and hence "healthy" undoubtedly lack the energy, recuperative powers, and "harmony of organic functions" required for the full enjoyment of life. Although these individuals are considered "healthy" by current medical standards, they are not getting what they should out of life. In many cases, they can be expected to succumb prematurely to chronic diseases.

It is difficult to formulate a complete definition of health in general terms. Today, "glowing health," to use an old phrase, is very uncommon among adults. As a result, we are usually constrained to think of it not as the attribute of a population but rather as that of a few individuals. We have not yet determined the potentialities of physical development for the community as a whole. Anthropologists and physicians have explored the relics of the past and traveled to remote primitive areas in an attempt to find evidence of robust, healthy communities. These explorations have yielded a great deal of useful information, but very few of the reports give us an adequate idea of what health could be if science and technology were placed completely in the service of human needs. Man is capable of being a great deal more than he is today - physically as well as intellectually - if his resources are employed in a rational manner.

The term "rational" should not be taken to mean natural or primitive. Man could not have advanced beyond a level of precarious subsistence if he had not consciously altered his natural environment and hammered it into a form that favored human life. The change was made at the expense of other species and, to some extent, by violating time-honored ecological relationships. Civilization was achieved by clearing forests, draining swamps, restricting animal predators, replacing many wild botanical species with food plants, fertilizing the soil, cultivating crops, probing the earth for fuels and metals - in short, by rearranging the natural world to satisfy human needs for food, shelter, and leisure. Modern man now has the power, knowledge, and resources to do substantially better than both his ancestors and his primitive contemporaries. His technology and science have given him an enormous influence over many natural forces. Chemistry has illuminated part of the darkness that once surrounded important aspects of soil development, nutrition, and physiology. In conjunction with research in microbiology and physiology, it has given society powerful therapeutic agents, such as antibiotics and hormones. Technology can

remove much of the drudgery that burdens human life and leave men free to use their bodies and minds for highly satisfying activities. Work can be pleasant as well as useful. Neither science nor technology, however, is a substitute for a balanced relationship between man and nature. Medicine and machinery may modify this relationship, but they cannot replace it. Few drugs are as effective as biological resistance to disease; no system of technology is likely to free man from his dependence on soil, plants, and animals. The two spheres, natural and synthetic, must be brought into a complementary relationship based on a clear understanding of man's needs as an animal organism and the effects of his behavior on the natural world.

A study of the interaction between man and nature may be called human ecology. Our synthetic environment is the product of man's interaction with the natural world, just as a dam is the product of a beaver's interaction with a stream and forest. The impoverishment and destruction of the soil, repeated insect infestations, and the rising incidence of certain diseases represent the reaction of the natural world to man's adverse environmental changes. To become what biologists term a "dominant organism," man is compelled to make sweeping demands upon nature, but nature, in turn, makes demands that man must fulfill if he is to enjoy health and well-being. Whether he likes it or not, there are "rules of the game," which must be obeyed if an environmental change is to advance human vigor, resistance to disease, and longevity. When these rules, simple as they may be, are transgressed, nature takes its revenge in the form of ill health and disease. When they are obeyed, man's life can be full, creative, and remarkably free of physical impairment.

## Ecology and Health

In a witty review of popular attitudes toward food, David Cort remarks that he has encountered absurdly conflicting dietary recommendations in books and articles on nutrition. One authority advises his readers to avoid fat; another advises that it should be eaten, on the theory that fat is the least fattening of all foods. Potatoes have been alternately damned and praised; mixed meals have been both frowned upon and approved; the consumption of alcohol, criticized and recommended. "The cruelty and irresponsibility of offering one single, standard dietary solution for everybody is obvious," Cort adds. "What a person eats is, in many important respects, his life. But every individual is different from every other individual. No doctrinaire solution will work for them all. Each individual has conditioned habits of eating, of taste, of appetite, of expenditure of energy, of nervous rhythms and, most important of all, of metabolism. Few modern doctors have the interest, time or genius to find out all about any one individual; and many are themselves overweight. But the individual has the time and interest and, at least about himself, perhaps the genius. After all, it's his life."

Although Cort's remarks are confined to nutrition, they are quite relevant to a number of problems in human ecology. It would be an error to form rigid concepts of a normal man, a normal diet, or a normal way of life. Any such image would be woefully lacking in biochemical and physiological support. The biologist and physician must still admit, as Carrel did nearly a quarter of a century ago, that "most of the questions put to themselves by those who study human beings remain without answer. Immense regions of our inner world are still unknown." Impressive advances, to be sure, have been made during the past two decades in solving major problems of cellular biochemistry, endocrinology, and physiology. Knowledge of the transformation of

energy in the cell is very far advanced, for example, and great strides have been made in understanding the chemistry of the genetic material in the cell's nucleus. Despite this newly acquired knowledge, however, nutritionists have an extremely limited understanding of the function of many trace elements in the body and of the way in which vitamins prevent deficiency diseases. The nutritional requirements of the various tissues, essential details of the blood-forming system, the mechanisms of resistance to disease, and many key relationships within the body await clearer understanding.

The human organism is extremely sensitive to very small quantities of hormones and nutrients. A variation by only a few drops in the daily output of insulin, a pancreatic hormone, will determine whether an individual will handle sugar properly or succumb to diabetes. A difference of a few thousandths of a gram (milligrams) in the intake of certain vitamins and trace elements makes for either well-being or nutritional disorders. According to the National Research Council, a man twenty-five years of age requires a daily intake of 1.6 milligrams of thiamine and riboflavin, 7.5 milligrams of vitamin C, and 12 milligrams of iron to preserve good health. His minimum daily requirements of iodine and copper are believed to be as little as 0.1 and 0.2 milligrams, respectively. If the daily intake of these nutrients is reduced by a few thousandths of a gram or less for a long period of time, the result will be a marked impairment of health. Despite the minute quantities involved, deficiencies of vitamins and minerals occur on a fairly large scale in the United States. If A. F. Morgan and L. M. Odland are correct in their claim that a dry, roughened skin and lesions of the eyes and mouth "may be considered a useful pointer to possible dietary faults," about 50 per cent of the adolescents examined in the affluent northeastern states and 20 per cent in the western states may have nutritional disorders.

We tend to look upon diseases as though they were localized disturbances, confined to definite parts of the body. Although it is customary to acknowledge the body's unity in sickness and in health, the whole is often overlooked in favor of the parts, and vital interrelationships are ignored in favor of isolated events. Actually, every major deficiency and physical impairment has far-reaching effects. "Disease consists of a functional and structural disorder," Carrel notes. "Its aspects are as numerous as our organic activities. There are diseases of the stomach, of the heart, of the nervous system, etc. But in illness the body preserves the same unity as in health. It is sick as a whole. No disturbance remains strictly confined to a single organ. Physicians have been led to consider each disease as a specialty by the old anatomical conception of the human being. Only those who know man both in his parts and in his entirety, simultaneously under his anatomical, physiological, and mental aspects, are capable of understanding him when he is sick."

A clear understanding of illness and health requires a greater appreciation not only of man but of men. Physical needs and responses vary enormously from one individual to another. Roger J. Williams, one of America's most eminent biochemists, emphasizes that within the same racial groups, even in the same families, men differ from one another in the shape and weight of their vital organs, the composition of body fluids, the output of endocrine glands, the rate of metabolism, temperature control, and many other respects. Individual differences in the amount of nutrients required for health and in the amount of nutrients absorbed by the body are of major practical importance. Individual requirements of calcium, trace elements, amino acids, and vitamins are highly variable. For example, two normal five-year-old children who ate the same food and were exposed to the same environmental conditions showed a great variation in the amount of calcium they retained from their diets. One child retained 264 milligrams of calcium per day for 45 days,

whereas the other retained 469 milligrams, a difference of nearly 80 per cent. A high degree of variability is also found in individual responses to common environmental toxicants. Williams cites an account of 78 men who were exposed to vapors of carbon tetrachloride, of whom 15 suffered acute poisoning. Six became sufficiently ill to require hospitalization. "All were white men within 5 to 8 years of the same age and in general good health...," observes Fredrich H. Harris, the source for Williams's account. "All 15 of the men poisoned were exposed from 3 to 8 hours; however, many of those who developed no symptoms were exposed for a similar length of time or longer."

The fact that man's knowledge of important bodily processes is incomplete and that many individuals exhibit marked deviations from "normal" responses and needs does not imply that the role of medicine is inconsequential in promoting health or that scientific generalizations are useless. The healthiest of men will undoubtedly require medical attention at some time in their lives, and every physician must use physiological and anatomical generalizations as points of departure for the diagnosis of a disorder. Basic research in biochemistry and physiology promises to increase vastly our understanding of the preconditions for human health and well-being. But a phenomenon does not cease to exist because it cannot be readily explained by current methods and theories. On the contrary, we are often profoundly affected by phenomena that are too complex to lend themselves to precise analysis at the present stage of scientific development. The way in which stress produces illness and the role that nutrition plays in the occurrence and prevention of chronic diseases constitute fields of research that have scarcely been penetrated. It would be a major setback if the roles of these factors were minimized simply because they present formidable problems to research. Man must try to conserve many practices that, on the basis of long experience, are known to promote good health, even if the reasons why they are beneficial cannot be stated in precise biochemical terms.

What are some of these practices? As it is clear that our bodily functions are interdependent, we should not permit any part of our biological equipment to atrophy. This means that we must use all the parts of our bodies. Our musculature must be as fully employed as our minds. Many activities and experiences that have been restricted by our sheltered civilization seem to play important roles in preserving health. There is a suspicion that modern man indirectly harms his body by failing to use certain physiological resources that once supported his ancestors during periods of hunger and cold. "There exists in the body of man, as of all animals, biological mechanisms for the storage of food developed for meeting the irregularities and cyclical changes in nature," Rene Dubos writes. "It may still turn out that a nutritional way of living permitting continuous growth at a maximum rate may have unfortunate distant results. Fasting fads may have some justification after all by providing an opportunity for the operation of certain emergency mechanisms built by nature into the human body."

Although it remains to be seen whether this conclusion will be accepted by nutritionists and physicians, it is reasonably clear that a one-sided manner of life is biologically undesirable. An existence anchored in either muscular exertion or inactivity, surfeit or poverty, stress or an overly sheltered manner of life, tends to produce physiological disequilibrium. A prolonged period of muscular exertion causes marked damage, whereas protracted physical inactivity appears to increase both the effect and the incidence of heart and circulatory disorders. When the coronary arteries of dogs are surgically narrowed to simulate atherosclerosis, a lack of exercise makes it difficult for new blood vessels to form and provide more blood to nourish the diseased area of the heart muscle. There also seems to be more coronary illness among men whose occupations are

sedentary than among those who engage in physical work. In contrast to the well-exercised individual, the "physically inactive individual shows signs of aging earlier in life," emphasizes Hans Kraus, of New York University. "He exists physiologically at a lower potential and is less well-equipped to maintain homeostasis [stable bodily conditions] and to meet daily stresses. This low level of function, combined with enforced suppression of the 'fight and flight' response, enhances the incidence of disease."

Not only does health require all the elements of a full life; it also requires that they exist in balance. A moderate amount of exertion, a balanced intake of nutriment, and a reasonable amount of exposure to stress are necessary for the maintenance of well-being. Almost any kind of excess is harmful. This has become apparent in respect to nutrition. "In laboratory experiments rats fed an unlimited diet were found to die sooner than animals prevented from gaining weight by a diet severely restricted in quantity but well balanced in composition," Dubos observes. "Likewise insurance statisticians have repeatedly emphasized that in man the obese have a short expectancy of life. Indeed, obesity is now publicized as the most common nutritional disease of Western society. This was apparently true also in Imperial Rome, as during all periods of great material prosperity. (And in periods of social decline and demoralization as well. The pursuit of "pleasure," which affluent Romans of the Imperial Age carried to the point of license, would have been frowned upon during the Periclean Age, when ancient Athens, too, enjoyed "great material prosperity.") 'In the old days,' wrote Lucretius in the fifth book of *De Rerum Natura*, lack of food gave languishing limbs to Lethe; contrariwise today surfeit of things stifles us.' Thus, history repeats itself. Like the prosperous Romans of two thousand years ago, countless men of the Western world today are digging their own graves through over-eating."

Finally, if man is to maintain good health, he requires diversity. It is hardly necessary to emphasize that a healthy psyche and a rounded response to stress are nourished - by a variety of experiences and by diversified surroundings. However, it does need to be emphasized that variety is also necessary for the satisfaction of man's nutritional needs. By limiting his selection of foods, he may fail to acquire nutrients known to exist in natural foods but not yet identified by chemists or nutritionists. "Because we know that unidentified factors exist in foods of plant and animal origin," observes George M. Briggs, of the National Institutes of Health, "it is wisest to eat a wide variety of foods from the many excellent food groups..." If this is done regularly, Briggs emphasizes, it is unnecessary to supplement the diet with vitamins and so-called health foods. It might be added that if food such as grain were not overly processed, it would be unnecessary to "enrich" bread with synthetic vitamins, which replace only part of the valuable nutrients lost in the milling process. In general, the more a food is processed, the greater the likelihood that identified nutrients as well as unidentified ones will be removed.

Completeness, balance, and diversity should be regarded as practical ecological concepts - as important in producing healthy human communities as they are in producing stable plant-animal communities. Indeed, it is not farfetched to say that when these concepts are correctly applied, they promote human health because they produce a stable ecosystem of men, animals, and plants. In the last analysis, the ecology of health is grounded in natural ecology. A complete way of life for man presupposes unrestricted access to the countryside as well as the town, to soil as well as to pavement, to flora and fauna as well as to libraries and theaters. A balanced way of life presupposes a lasting equilibrium between land and city; animals, men, and plants; air, water, and industry. Diversity presupposes an awareness that nearly every species perpetuates the stability of the biosphere, either directly or indirectly. As the city encroaches on the land, however, human

life becomes increasingly restricted to a polluted, nerve-racking urban environment. As the city begins to dominate the land, physical activity yields to sedentary forms of work. Finally, as the aggregations of population swell to massive proportions, foods become laden with chemicals and human activities are standardized. By oversimplifying the natural environment, we have created an incomplete man who lives an unbalanced life in a standardized world. Such a man is ill - not only morally and psychologically, but physically.

## Ecology in Use

Our environmental difficulties would be understandable if we knew nothing about the requirements for a balanced relationship between man and nature. We could then answer every reproach with a confession of ignorance. Today, however, we know too much about ecology to have any excuse whatsoever for many of the abuses that are perpetrated in agriculture, food production, and urban life. The time is approaching when the ad hoc measures with which we have tried to stave off the problems of environmental change will have to be supplanted by lasting ecological solutions.

Ecology, as has been noted in an earlier chapter, deals with the interrelationships of living things (including man) and their environment. The more these interrelationships are explored, the more evident become the interdependence of most organisms in a given locality and the needs that each species fulfills for the others. Most ecological studies are limited and highly concrete, but the material at hand suggests a number of practical generalizations that are relevant to the problems discussed thus far, particularly those of agriculture and land use.

A rational agricultural program must begin by taking into account the natural characteristics of the soil. "Soil productivity is not simply a matter of available chemicals," observes Edward Higbee, of Clark University. "It is also heavily dependent upon good structure, aggregation, texture, mellowness, and micro organic life." Many of these characteristics are predetermined by the natural history of a given area, including its ecology under virgin conditions, its underlying rock formation, and its prevailing climate. In addition, there are likely to be important differences in the soils of individual farms owing to variations in the slope of the land, in drainage conditions, and in the depth of the solum, or true soil, in relation to underlying layers of clay and rock. The configuration of the land determines, to a large extent, the optimal conditions of growth for different kinds of vegetation, especially in rolling or hilly country. Some areas will be best suited for pasture, others for field crops. On many farms in eastern sections of the United States, a sizable acreage of land should almost certainly be returned to timber. Attempts to exploit these soils for the cultivation of food and grazing often result in extensive erosion and unsatisfactory crops.

If no attempts were made to modify a natural ecological pattern, agriculture would be impossible, and, in many cases, superbly improved crop lands would be reclaimed by the forest and irrigated soils would again become unproductive. But we cannot ignore the ecological factors that clearly limit the cultivation of many foods. Large areas of land are now supporting crops for which they are definitely not suited, and society would profit more by giving a freer rein to nature than by forcing the soil to produce a low quality of vegetation. The dry plains from the Dakotas to western Texas, for example, were meant to be range lands, not crop lands. Weather conditions are too uncertain for the cultivation of grain, and the area suffers from repeated sieges of drought, whose effects are only aggravated by the systematic cultivation of food. The produc-



tivity of the arid plains is notoriously low, and attempts to grow commercial crops have resulted in widespread deterioration of the soil.

In most cases, the best soils of the world were developed under highly varied forms of vegetation. Although certain plant groups seemed to dominate the landscape of particular regions, a closer view usually disclosed a great diversity of species. The uniformity of the American prairies, long regarded as a "desert of grass," was an illusion. "Many virgin forests cannot display so great a variety of plant and animal life as the now nearly vanished native grasslands..." Higbee writes. "For the patient individual who walks slowly and watches closely it is a world of infinite variety in small forms and subtle colors." Although agriculture can never completely restore this variety, it can try to approximate it, not only to please the eye but to create a more complex ecological pattern for purposes of controlling pests and conserving the soil. Indeed, it would be wise to diversify as well as to rotate crops. Certainly no moderate-sized farm on forest soils should be without timber, and even on the prairies it is no longer necessary to prove to the farmer that he has much to gain by planting trees as shelter belts against the wind and as oases for bird life.

To achieve a lasting, stable agriculture, we must reserve a place for livestock on the modern farm. Not only are meat and dairy cattle sources of manure, but their mere presence tends to restrain the exploitation of crop lands. Most farmers who own herds of cattle are obliged, in order to feed the animals, to cultivate soil-protecting legumes; willingly or not, they thus follow practices that conserve the land. On the whole, however, the trend has been away from mixed forms of agriculture, in which both food plants and livestock are raised on the same agricultural unit. The small farmer, faced with heavy competition from larger enterprises, has begun to specialize; he either raises livestock or cultivates a limited number of commercial crops. Dairying, one of the most important forms of mixed agriculture, is more or less on the decline throughout the United States, except in parts of the South. The number of cows and heifers kept for milk has dropped more than 20 per cent since 1945.

It need not be emphasized that the oversimplification of agriculture creates ideal conditions for the invasion and proliferation of pests. But even variety in plant life and the presence of livestock are not likely to be effective in helping to control pests if the land is being exploited. Ecologists have found that an overgrazed range, for example, tends to attract a large number of rodents and insects. "It is generally observed... that jack rabbits are usually most numerous where the range is poorest and the grass most sparse," notes Edward H. Graham, of the U. S. Soil Conservation Service. In a discussion on insect pests, Graham adds: "Even the abundance of grasshoppers, so destructive of crops and range vegetation, can be related in some degree to intensity of land use. Weese... has been credited with the statement that a barbed wire fence is the best device for controlling range insects, meaning that controlled grazing which permits good grass will automatically reduce the number of injurious insect forms."

The effective control of pests requires an appreciation of many complex factors, some of which may seem; far removed from the outbreak of an infestation but play, an important role in its occurrence. Albrecht has placed a great deal of emphasis on the role of soil fertility in building up the resistance of plants to insect predators. Research at the University of Missouri suggests that certain species of insects are attracted to crops grown on deficient soils. As soil fertility is improved, the infestation declines. Each host plant and each insect species, of course, constitutes a separate problem that can be solved only on its own terms. Unwise methods of fertilizing the soil may actually make it easier for an infestation to occur. For example, if nitrogen fertilizer is used excessively, it produces heavy vegetative growth, but the maturity of the plant is delayed

and its cell walls are thin and are easily penetrated by disease-causing organisms. These lush, immature plants, low in resistance to pathogens, tend to attract insect predators and often pave the way for a serious infestation.

One of the most harmful misconceptions in agriculture is that all predators of crops are exclusively injurious and should be completely destroyed. Mention has been made of the valuable role played by forest rodents in limiting insect infestations (see pages 56-7); similar evidence can be adduced from areas such as the plains, where rodents have been singled out for vigorous extermination campaigns. In a study of the high plains grasshopper, Claude Wakeland observes that in some areas, rats, mice, and gophers "have devoured a great many grasshopper eggs, nymphs, and adults. Doubtless they have destroyed various forms of the species far more extensively than the meager data available indicates." On the plains, rodents have become pests as a result of overgrazed ranges and the extermination campaigns conducted against the coyote, which feeds primarily on carrion and small mammals. Ecological studies show that 20 per cent or more of the coyote's diet consists of insects; during periods of heavy infestations, it feeds almost exclusively on grasshoppers. To be sure, biological control of pests, as distinguished from chemical control, is not a cut and dried affair. Many different approaches will have to be combined before the problems of pest control can be effectively resolved. But unless these methods are adopted and, above all, creatively integrated to suit the needs of each region, the use of pesticides will increase steadily in the years to come.

Another prevalent misconception about agriculture is that bigness per se makes for efficient and rational use of the land. The small farm has a potential advantage that the land factory and its close cousin, the plantation, seldom enjoy. A moderate-sized farm is dimensioned on a human scale. It lends itself to close scrutiny and careful management, to an intimacy between the farmer and the land that could engender a greater sensitivity to different soil needs and promote the employment of sound ecological practices. Small-scale farming could be successfully pursued as a form of applied ecology if blind economic interests were replaced with a sense of social responsibility. Unfortunately, many small farms in America are miniature replicas of the land factory. Agricultural units, large and small, tend to share the same ends - the "mass manufacture" of crops at the least cost.

A balanced system of food cultivation based on highly diversified, small-scale farms is not a utopian vision. The small farm still constitutes the backbone of agriculture in many areas of Western Europe. Over many centuries heavy forest soils were slowly reconstructed to support livestock, orchards, and a large variety of field crops. Today, a diversified system of small-scale agriculture prevails in England, France, Scandinavia, and parts of West Germany. Most European farms, to be sure, are hardly models of good food cultivation; they often fail to make use of the ecological possibilities that exist in the moderate-sized agricultural unit. In contrast with most American farms, however, many European farms have created a workable relationship between man and the soil. These farms enjoy relatively high soil fertility despite centuries of use. Organic matter is often carefully returned to the land, and an entrenched tradition still resists the complete chemicalization of agriculture in many parts of England, France, and Germany.

So much for the dictates of ecology. If these dictates seem "unrealistic," it should be noted that in England today about 75 per cent of the farms have less than 300 acres and the average is about 100 acres. Agriculture in England and Wales has largely been stabilized around a small, highly diversified farming unit, almost equally divided between pasture and crop lands. Although many of these farms have been cultivated for 500 years or more, they have a far greater yield

of wheat per acre than the average American agricultural unit and compare favorably with the latter in the output of other crops. American agriculture, driven by competition and an appetite for high earnings, is so much in flux that it is difficult to speak of sanity, still less of stability, in many rural areas of the United States. What is the trend? Robert S. McGlothin, of the Stanford Research Institute, suggests that by the end of the century, the number of American farms will have declined from 1.7 million to between 300,000 and 400,000. These large agricultural units will produce about 90 per cent of the food cultivated in the United States. "Commercial farmsteads will be laid out and run like highly mechanized industrial plants. Crop and livestock production will be integrated into a comprehensive materials handling and marketing system. The independent family farmer will hire management counseling, which, with the aid of electronic computers, will help him program the operation of the entire farm system so as to achieve lowest unit costs of production. The computer will indicate - for each production season - which crops should be grown, where, in what quantities, when they should be fed to what livestock, and when and where marketed for greatest return."

To many, this may seem to be progress. To the ecologist, however, it represents an attempt to bring the laws of the biosphere into accordance with those of the market place to reduce the natural world to merchandise. Nutritious crops can no more be expected to grow according to commercial schedules than man can be expected to adjust his pulse to the rhythm of machines.

# CHAPTER EIGHT: HEALTH AND SOCIETY

## Individual and Social Aspects of Health

A new approach is likely to gain easier acceptance if it involves individual rather than social action. The majority of people tend to look for immediate, practical solutions that they can adopt without having to face major social and environmental problems. They search for personal recipes and formulas for physical well-being. This attitude is understandable. Health and illness are intimate problems, involving the ability to survive and enjoy full lives. Health is enjoyed by the individual, not by such abstractions as "man" and "the community." Any discussion of health usually evokes the query: "What can I do right now to remove hazards to my health and assure my physical well-being?"

This question has been answered, to a great extent, by authorities cited in the previous chapters - implicitly if not always directly. Diet should be highly varied. If at all possible, it should be based on foods that receive minimal or no treatment by processors, such as whole-wheat breads, fresh meat, vegetables, and fruit. Weight control is desirable in all stages of life, not only in middle age. Urban man should put his body to frequent use, with an emphasis on mild daily exercise, such as walking, rather than on sporadic sessions of competitive sports. Certainly smoking is utterly incompatible with good health and should be reduced or eliminated.

There is a good deal of evidence to indicate that a high intake of starches, sugars, and polysaturated fats predisposes the individual to coronary heart disease. At any rate, a diet that is ordinarily regarded as suitable for active growing children seems to be very undesirable for adults. (Let us pause to note that as little as fifteen or twenty years ago any plea for a reduction in the intake of eggs and dairy fats would have been furiously denounced by most nutritionists as "cultism" and "food faddism." Nutritionists tend to form ironclad opinions that are difficult to alter without long, often heated controversy, it is not uncommon to find nutritionists who still regard the dietary suggestions of Ancel and Margaret Keys in *Eat Well and Stay Well* as being a hairbreadth away from "quackery." The study of the human diet and its effects on health would benefit immensely if more investigators were willing to follow less conventional and more independent lines of inquiry.) The food intake of the individual should be carefully scaled to his age, to his work load, and to his activities during leisure hours.

The individual should attempt to cultivate a serene attitude toward the surrounding world, an outlook based not on a psychoanalytic accommodation to the ills of society, but rather on a critical sense of values that places the trivia of daily life in a manageable perspective. To seek an uncritical, brainless state of euphoria is self-debasing. On the other hand, to respond with equal sensitivity to every disquieting aspect of daily life is spiritually paralyzing and physically harmful. In trying to reduce the tensions that an overly urbanized, bitterly competitive society engenders in the individual, there is no substitute for a truly humanistic philosophy that helps us to discriminate between problems that warrant a strong emotional response and those that

should be dismissed as inconsequential. To live a life without intense feeling is as dehumanizing as to live one that is filled with ill-defined, persistent agitation.

Health is the result of a lifelong process. It cannot be acquired by a pill or by a "magic" food. Physical wellbeing presupposes a rounded mode of life and a comprehensive diet geared to the needs of the body. Any attempt to prescribe a single "health-giving" recipe that fails to encompass the totality of the individual - his past as well as his present - is irresponsible. Neither "royal jelly" at one extreme nor a "miracle drug" at the other will provide an individual with health if his environment and manner of life are deteriorating. Attempts to resolve health into a single formula may be well-meaning, but they are woefully incomplete.

The need for a comprehensive approach to health is stressed in Iago Galdston's critique of modern medicine and his argument for social medicine. Modern medicine has failed, in Galdston's opinion, not because it has "no cure for cancer, for essential hypertension, or for multiple sclerosis. Were it to achieve these and other cures besides, it still would have failed." Its failure is due to the fact that "modern medicine is almost entirely preoccupied with diseases and with their treatment, and very little, if at all, with health. It is obvious that an individual sick with pneumococcus pneumonia can be effectively treated by chemo-therapeutic agents, or by antibiotics. But such an individual, though cured of his pneumonia, may, and most likely will, remain a sick man unless, in addition, efforts are made to help him regain his health." Galdston advocates more than convalescent care. He proposes a change in medical education, medical outlook, and medical methods. A physician trained according to the principles of social medicine "would not be moved to inquire 'what's he got and what's good for it,' but, confronted by an ailing individual, he would attempt to determine the nature and extent of the disability as it is manifest, not merely in the presenting symptoms, but in the overall performance of the individual according to his position in life; that is, in the light of his age, educational, vocational, social, and other prerogatives and obligations. He would not affirm 'this man has a peptic ulcer,' and undertake to treat the ulcer, but would by the presence of the ulcer recognize that the individual is sick and seek to determine and to correct, or amend, what ails the individual; what, in other words, impedes the individual in the fulfillment of his adventure in living."

Galdston's remarks constitute a much-needed attempt to widen the contemporary medical outlook. Efforts to expand prevailing notions of illness, treatment, and health beyond the germ theory and the emphasis on specific cures for specific diseases were thwarted at the turn of the century. This defeat culminated in tragedy when Max von Pettenkofer, the great German sanitarian, took his life in 1901 in despair over the rejection of his viewpoint. Pettenkofer had never denied the germ theory of disease, regardless of popularizations of medical history to the contrary. The controversy in his time centered around whether germs alone caused disease or whether environmental conditions and the constitution of the individual should also be considered in the study of individual illness and epidemics. As John Shaw Billings, the great American authority on public health, put it in 1883: "It is important to remember... that the mere introduction of germs into the living organism does not ensure their multiplication, or the production of disease. The condition of the organism itself has much influence on the result... Pasteur has certainly made a hasty generalization in declaring that the only condition which determines an epidemic is the greater or less abundance of germs."

Today, three generations later, the issue is being raised again - and in what appears to be a much broader sense than even Galdston has suggested. Many of the biological problems created by poor sanitation and slums have been resolved, at least in the Western world. We are no longer as

deeply concerned with killing epidemics of communicable diseases as were Pasteur, Pettenkofer, and Billings. But we are very much concerned with harmful environmental influences on some of the most intimate aspects of individual life. The necessities of life, even its pleasures, are now being manufactured for the millions.

As a nation of urban dwellers in a mass society, we are becoming increasingly dependent upon the decisions of others for the quality of our food, clothing, and shelter. These decisions affect not only our diet and our private lives; they affect the water we drink and the air we breathe. To speak of an environmental "influence" on health is an understatement; there is a distinct environmental and social dimension to every aspect of human biology. Man today is more domesticated than he has ever been in the long course of his history.

It is here that we encounter the limits of the individual's ability to attain health on his own. The average man finds it extremely difficult to reorganize his mode of life along lines that favor well-being and fitness. If he lives in the city, he cannot possibly avoid exposure to air pollutants. Similarly, there are hardly any rural areas in America where the individual is not exposed to the assortment of pesticides that are currently employed in agriculture. Any serious attempt to limit the diet to pure foods, free of pesticide residues, artificial coloring and flavoring matter, and synthetic preservatives, is well beyond the financial means of the average person. But even if the individual can afford it, he will find that untreated foods are difficult to obtain, for relatively few pure foods are grown in the United States and those that reach urban centers are rarely sold in large retail markets. The layout of the modern city and its routine demands on the urban dweller tend to discourage a physically active way of life. Movement in the large city is organized around the automobile and public means of transportation. Most of our occupations and responsibilities demand mental dexterity, a routine of limited physical work, or rapid communication. It requires a heroic effort to walk instead of ride, to do instead of see, to move instead of sit. Although a few exceptional individuals may succeed in modifying their mode of life in a way that promotes health, the overwhelming majority of urban dwellers can be expected to go along with things as they are.

Does this mean that modern man will never attain optimal health, that it is, in fact, a "mirage"? Rene Dubos has argued rather persuasively that health is a relative concept. Man's criteria of health change with the economic, cultural, and political goals of each social period. "Clearly, health and disease cannot be defined merely in terms of anatomical, physiological, or mental attributes," Dubos writes. "Their real measure is the ability of the individual to function in a manner acceptable to himself and to the group of which he is part... For several centuries the Western world has pretended to find a unifying concept of health in the Greek ideal of a proper balance between body and mind. But in reality this ideal is more and more difficult to convert into practice. Poets, philosophers, and creative scientists are rarely found among Olympic laureates. It is not easy to discover a formula of health broad enough to fit Voltaire and Jack Dempsey, to encompass the requirements of a stevedore, a New York City bus driver, and a contemplative monk."

Perhaps so. But the truth is not exhausted by the limited notions men form of a given event or situation. That which individuals, classes, or communities really believe to be health in a given historical period - all pretensions aside - does not tell us what health could be or what it should be in a broader biological and social perspective. It is one thing to say that historical notions of health have been limited; it is quite another to contend that they will always be limited. Although Dubos may be correct in describing life as a series of ideals for which men can be expected

to sacrifice their health and even their lives, there is no reason to believe that health, defined primarily "in terms of anatomical, physiological, or mental attributes," is incompatible with a rational manner of life. On the contrary, a manner of life that promotes health is likely to be more satisfying culturally and socially than one that militates against the attainment of fitness and well-being. Health is nourished by all the environmental and social factors that advance thought, creative effort, and a rounded personality. The social factors that promote health also promote the adventure of life.

On the other hand, the more cloistered the man, the more cloistered the mind. The more one-sided the way of life, however "challenging" or "adventurous" it may seem on the surface, the more limited the range of thought and art. Voltaire was a brilliant writer but a superficial thinker. His life, spent for the most part at the chateau of Cirey and in his '1airs" on the Franco-Swiss border, shows in his work. One is entitled to wonder whether he would have acquired greater depth had he been exposed, like his more profound contemporary, Diderot, to an earthier life in the streets of Paris. Similarly, Olympic laureates seldom become poets and philosophers because their limited notions of "adventure" are focused entirely on physical activity for its own sake. Far from challenging the "Greek ideal of a proper balance between body and mind," the very incompleteness of their lives and thought is evidence of its validity.

Dubos, in effect, tends to equate health with adaptation. The environments to which men are expected to adapt are conceived of as dynamic, emergent phenomena - a rather ambiguous approach that seems to take the environment too much for granted. Unlike other animals, man can consciously remake his environment, within certain limits, and the real issue to be faced is whether it is man or his unsatisfactory environment that should be changed. Viewed from this standpoint, the problem becomes much clearer. One can conceive of many circumstances in which health is not an end in itself and even of circumstances in which the achievement of certain ends is worth the loss of health. By and large, however, a health-promoting environment encourages social and cultural progress. There need be no conflict between health and a truly creative, rational civilization.

On the whole, however, Dubos has performed a notable service in focusing attention on the relationship between human fitness and social development. We cannot conceive of progress in the field of public health without advances in society. Management of the soil has always depended upon the prevailing forms of land tenure. The quality of today's food is partly determined by whether the interests of food manufacturers or the interests of consumers determine technological changes in the industry. The form and direction taken by urban life are guided by the kind of social relations men establish in the management of their affairs. Any attempt to preserve the health of individuals which does not also aim at creating social patterns that will favor the health of mankind as a whole may result in limited improvement but not long-range solutions. The majority of individuals who seek optimal health as soloists in a deteriorating environment have far too much to cope with in attaining their ends.

At the same time, today, more than at any other time in history, every social change has deep-seated biological consequences. Man has developed extremely effective methods for changing the world around him. The results of his activity over the face of the earth are far-reaching. The natural world can no longer successfully oppose dense forests, vast bodies of water, and climatic rigors to his penetration. The developments of modern technology have deprived nature of its old defenses against the invasion of man. But the natural world can strike back in the form of disease, exhaustion of the soil, and desiccation of the land. The importance of caution and

the need for exercising reason in changing the world around us can hardly be given too much emphasis. 'What is new is not necessarily good,' Dubos observes, "and all changes, even those apparently the most desirable, are always fraught with unpredictable consequences. The scientist must beware of having to admit, like Captain Ahab in Melville's *Moby Dick*, 'All my means are sane; my motives and objects mad.'"

## The Problems of Remedial Legislation

How much progress can we expect from attempts to improve the health of the American public by means of legislation? More, certainly, than we can expect from isolated individual efforts. The United States has by no means exhausted all the possibilities of welfare legislation; it has lagged behind many European nations in fulfilling its responsibilities to the sick and the infirm. Its national health programs consist of ad hoc aid and a patchwork of laboratories and clinics to meet the mounting needs of research and therapy. Food and drug laws have not kept pace with the rapid changes in food technology, and the operations of federal agencies responsible for administering them leave much to be desired. An account of the advances, conflicts, and retreats in the field of food and drug control offers a valuable perspective on what remedial legislation can and cannot be expected to do.

The problems of food and drug control have been surrounded by such a dense fog of official overstatement that almost any criticism of existing laws and agencies invites countercharges of "quackery" and "faddism." Consider the following blurb, made up in part of official statements, which the public is expected to accept as good coin:

'When the American housewife pushes her shopping cart through the supermarket, she can select attractively packaged foods and drinks with the confidence that they are honestly labeled, pure and wholesome. Her confidence is based on the existence of good laws that are vigilantly enforced. Most American food manufacturers today have the will and the know-how to produce the pure foods that she wants. They accept the Food, Drug, and Cosmetic Act as a blueprint of their obligations to the Nation's consumers. The additives that go into food are there to improve the food and bring it to the housewife in better condition and in a more convenient form. Reliable food processors have not reduced the nutritional quality of our foods or created inferior products through the use of chemical additives. Actually, the quality and sanitary characteristics of our food have been improving.'

Most of these complacent remarks can be dismissed as rubbish. Without doing any injustice to the facts, the blurb might be rewritten as follows:

"When the American housewife pushes her shopping cart through the supermarket, she encounters many products whose packaging often misleads her concerning the quality, quantity, and nutritive value of their contents. Generally, the enforcement of food-labeling laws and regulations has been handled in a very slovenly fashion by federal and state authorities. Most processed foods are certainly not 'pure,' if by a pure product is meant one that does not contain chemical additives. Food and drug control is far from satisfactory, and it has often been necessary to prod federal agencies into discharging their responsibilities to the consumer. The F.D.A. has shown an unusual susceptibility to influence from the food industry; the agency's performance has been distinguished by its leniency and patience with food manufacturers. More often than not, food processors and drug manufacturers have bitterly opposed improvements in regulatory legisla-



tion. Although some of the chemicals that are added to food may possibly improve them, the safety of many food additives is very doubtful. Finally, reliable food manufacturers have definitely reduced the nutritive value of certain common foods, and additives have often served to conceal inferior products."

The first statement attempts to evade the problems of modern food control; the second, to face them. It is almost begging the question to claim that producers of food accept the Food, Drug, and Cosmetic Act as "a blueprint of their obligations to the Nation's consumers" when the law is not as demanding as it should be and those who administer it are satisfied with a second-rate achievement. Nor is the case for the law strengthened by smuggling the housewife's "wants" into the issue. The wants of many consumers are created by high-pressure advertising and salesmanship. The average consumer knows far too little about nutrition to evaluate advertising claims. Food purchases are guided partly by sales technique, partly by the appearance of the food. Thus, the food industry tends to generate the very wants it professes to satisfy, and conventional books and articles on nutrition tend to equate the satisfaction of these industry-created wants with improvements in the quality and purity of our food.

The truth is that federal food and drug legislation has always been a poor, unstable compromise between the interests of the food industry and the demands of an aroused public opinion. More than a quarter of a century separates the first unsuccessful attempts to enact a general anti-adulteration law (1879) and the adoption of the basic Food and Drug Law of 1906. The story behind these and later conflicts in the field of pure-food legislation indicates the amount of effort that has been required to preserve the integrity of our food supply. The needs of industry were consistently given priority over those of the public; during this entire period, Congress was quick to favor special interests. It put an end to the export of adulterated products only when the reputation of American food began to decline on the world market. It enacted legislation against oleomargarine in behalf of domestic dairy interests. On the whole, the public interest was served only indirectly. At the turn of the century, the most flagrant cases of adulteration were the work of small-scale producers, whose adulterated goods placed major producers at a competitive disadvantage. In these cases, both Congress and most of the food manufacturers responded readily to the need for specific anti-adulteration legislation, but the food industry's support for a general food law was, at best, hesitant, and in the halls of Congress support for a pure-food law gathered very slowly.

It is extremely doubtful whether any general food and drug legislation would have been adopted in 1906 were it not for the efforts of Harvey W. Wiley and the unexpected support his efforts received from the publication of Upton Sinclair's *The Jungle*, a novel which criticized the social and sanitary conditions in the Chicago stockyards. Wiley was a gifted physician and chemist whose pioneering research in sugar, soil, and food analysis brought him to the position of chief of the U. S. Department of Agriculture's Bureau of Chemistry. His prestige as a scientist, his Hoosier wit, and his engaging personality gained him wide professional and public admiration. The task of ensuring a pure food supply for the American consumer became Wiley's life work. His lectures, articles, reports, and congressional testimony mobilized widely disparate groups - from urban civic clubs to farm organizations - behind the demand for a general anti-adulteration law. The food industry at first followed Wiley cautiously, later reluctantly, and finally, with few exceptions, turned against him. In the spring of 1906, when the issue reached its climax in Congress, opposition from the food industry nearly succeeded in preventing the enactment of an effective pure food and drug law. As late as June 1906, after much wrangling in the House of Representa-

tives, Wiley despaired of getting a law. "No serious attempts, so far as I know," he wrote, "have been made to set a date for its consideration."

The publication of *The Jungle* in book form (January 1906), however, had aroused widespread public indignation against the meat-packing industry. The scales were tipped in favor of the law when President Theodore Roosevelt released part of a report by a federal investigating commission which fully corroborated the details in Sinclair's novel. The national uproar that followed these disclosures threw the industry into retreat, and on June 30, 1906, the first federal Pure Food and Drug Act was signed into law. Its administration was placed largely in the hands of Wiley and his Bureau of Chemistry. Although the law had many shortcomings, some of which were corrected in later years, the high standards of food and drug control which Wiley sought to establish during his tenure in office have never been equaled by his successors. The history of the fight for pure food after Wiley's departure from government service reads like an anticlimax to the vigilance and dedication that marked earlier policies.

These policies were guided by two basic principles. The first was that the consumer should know precisely what he is getting and that he should get precisely what he wants. Wiley bitterly opposed labels or claims that misrepresented a product to the buyer, even if the use of a spurious description was harmless to public health. He stubbornly fought attempts by food manufacturers to describe glucose as "corn syrup" or to represent whiskey made partly of neutral grain spirits as "blended whiskey," a name that generally denoted a blend of several genuine whiskeys. For Wiley, a label had to be complete and truthful. He expected the food manufacturer to disclose all the artificial ingredients added to a product. The name on a package, can, or bottle had to convey the nature of the product without any ambiguity or misrepresentation.

Wiley's second principle was that if any doubt exists about the toxicity of a chemical additive, the doubt should be resolved in favor of the consumer. As it is impossible to prove a negative such as "harmlessness," Wiley argued, it is not permissible to use any questionable additive that is not indispensable to the production, storage, or distribution of food. If an additive contributed nothing to health or to the availability of a food, and if its use might conceivably prove harmful, the Bureau of Chemistry sought to have it removed. Wiley seldom wavered on this score; his decisions almost invariably favored the public interest.

Many people in the food and chemical industries felt differently, however, and their complaints evoked a sympathetic response from the government. By 1912, Wiley's attempts to execute his policies were being frustrated to such an extent that he left government service. With his departure, the law underwent steady reinterpretation. An increasing number of doubts about the toxicity of new chemical additives were resolved in favor of food growers and food processors. The Bureau of Chemistry and its successor in the enforcement of the law, the Food and Drug Administration, began to exhibit undue sensitivity to the financial welfare of industry. The improvement of food was equated with lower costs, attractive packaging, and sales-promotion devices. Wiley had combined the zeal of a crusader with the knowledge of a physician; with his departure, the policies of the federal regulatory agencies were guided increasingly by lawyers and professional administrators who began to give priority to legal considerations instead of problems of public health.

The consumer could ill afford this development. Although an overhaul of the food and drug law was made in 1938, the situation began to deteriorate to an appalling extent. After the end of World War II, the American food supply was deluged with an unprecedented variety of new chemical additives. DDT and other organic insecticides, unknown in 1938, were being used extensively in

agriculture and the home. The responsibility for proving that a chemical additive was harmful to the consumer rested with the F.D.A. Food growers and food processors were free to use what they chose until such time as the government could establish that the additives involved were toxic substances. Testing standards in many laboratories were inadequate; experimental work on new additives was often limited to sixty - and ninety-day feeding trials on one or two species of rodents.

In September 1958, Congress changed the law drastically; it made the manufacturer responsible for establishing the safety of a food additive and inserted the Delaney anti-cancer clause, a provision that flatly prohibits the use of additives "found to induce cancer when ingested by man or animal..." Although the anti-cancer clause was strongly supported by the American Cancer Society and by leading cancer specialists, it was opposed by the F.D.A. Testifying in April 1958 before a House committee studying pending revisions of the law, F.D.A. Commissioner George P. Larrick observed: "Two of the bills before you make specific mention of cancer." The F.D.A.-supported bill, H.R. 6747, does "not mention it specifically... This bill bars the use of an additive unless it is established that it is without hazard to health. Thus, the bill would prohibit the addition of any chemical additive to the food supply until adequate evidence, acceptable to competent scientists, shows that it will not produce cancer in man under the conditions of use proposed." Although Larrick endorsed the goal of "seeing that cancer-producing foods are not on the American market," Congressman Delaney reminded the National Health Federation that "in 1956 an FDA ruling permitted, at a certain concentration, residues of a pesticide to remain on marketed fruits and vegetables, even though it had been shown to induce cancer in test animals. Later tests showed this chemical to be even more injurious than the earlier tests demonstrated, and the FDA has now taken action to prohibit any of its residues on raw agricultural commodities."

The credit for finally adding an anti-cancer clause to the 1958 law must be given to Delaney, who saw to its enactment despite strong opposition from the food industry and the F.D.A. By 1960, the F.D.A. had reversed its position and, at the hearings on food colors conducted by the House Committee on Interstate and Foreign Commerce, expressed its fervent support for the Delaney clause. Presumably all is well that ends well, but the F.D.A. refuses to let the clause remain as it is. At the food-color hearings, the Secretary of Health, Education, and Welfare, Arthur S. Flemming, began to nibble at the Delaney clause by suggesting that it "should be modified to provide that additives used in animal feed which leave no residue either in the animal after slaughter or in any food product obtained from the living animal be exempt from the provisions of the clause. A comparable amendment to the anti-cancer clause in the color additive legislation under consideration would be appropriate." Experience with Yellow OB and Yellow AB suggests that such standards of purity are impossible to achieve (see page 139).

The sweeping legislative revisions of 1958 were not gained without a sacrifice. For all its shortcomings, the 1938 law had one redeeming feature: It flatly prohibited the use of any toxic chemical additives in food other than those that were clearly indispensable to food production. Although the burden of proof rested with the F.D.A. instead of the manufacturers, the 1938 law set a new functional standard for chemical additives in food. This criterion was dropped in the 1958 revisions of the law, largely on the urging of the food industry and the F.D.A. The burden of proving that the additives are safe has been shifted to the manufacturers, but toxic chemicals can now be added to food provided they are used in amounts that are deemed to be "harmless" to consumers.

Thus, after the passage of a half century, the law makes no attempt to resolve Wiley's original problem: Does an additive contribute to the nutritive value and availability of a food or does it

merely function as a dispensable technological aid? Modern refrigeration and canning techniques have eliminated the need for many artificial preservatives in our food supply. Hardly anyone will contend that coloring and flavoring matter are indispensable to food production. If consumers really desired artificial colors and flavors, they could be marketed as independent products and the public could use them at its own discretion. The food industry could modify its production methods so as to operate with a minimum number of chemical additives and with a view toward retaining many nutrients that are now lost because of an overemphasis on mass production and highly processed foods. Many synthetic additives that have no nutritive function could easily be replaced with valuable nutrients. For example, ascorbic acid (vitamin C) is a good antioxidant and an excellent flour bleach, but as it is relatively costly, it would be unprofitable to use it.

The food industry has demanded complete freedom in determining the function of chemical additives in food. The following remarks by the National Association of Frozen Food Packers are fairly typical: 'We join with other segments of the food industry in fundamental opposition to provisions which would permit the Food and Drug Administration to determine the composition of food products upon the basis of its conception of functional value or utility of food ingredients.' This seems to be a matter of principle, not a lack of confidence in the F.D.A. After asserting that the chances are "rather remote" that a food processor would engage in costly tests of a toxic additive, the association adds: "In any case, the question of usefulness of an ingredient shown to be safe is one which the manufacturer of a food is entitled to resolve upon the basis of his own experience, and is not properly a matter of the opinion of the Food and Drug Administration."

The F.D.A.'s superficial approach to food and drug legislation has largely been exhausted. The next overhaul of the law must return to the principles that guided Wiley a half century ago. Moreover, we require not only a better food and drug law but comprehensive national legislation that will confront the problems raised by urban and industrial pollution, radioactive contaminants, the misuse of X radiation, and industrial carcinogens. Water pollution can be appreciably reduced if all sizable communities are required to treat their sewage and if an effective national program is developed to reclaim and re-use water to meet industrial needs. The highest-quality water, that which requires a minimum of chemical treatment, should be reserved for drinking purposes. The problem of air pollution should be met resolutely, without qualms about cost and without fear of offending industrialists, motorists, or homeowners. Recently developed catalytic and non-catalytic burners, for example, can remove many harmful agents from automobile exhausts. "Automobile engineers know now that for perhaps \$10 per car they can eliminate 50 per cent of the hydrocarbons; for something over \$300 they can eliminate them almost totally," observes George A. W. Boehm, of Fortune magazine. "Any city or state that decides to apply air-pollution regulations to cars will have to decide how much the motorist can be made to pay for how much purity, and how far it is prepared to go in enforcing purity regulations."

But let us not deceive ourselves; an environment based on mammoth, expanding cities will never be a healthy one. In the United States, the ecological and nutritional problems created by monoculture and the land factory are likely to grow worse, and many chemical additives will be required in the mass production of our food. Insecticidal residues will undoubtedly continue to pervade our food staples. The substitution of nuclear energy for mineral sources of fuel will be accelerated in the years to come, and more radioactive substances can be expected to enter man's environment. Urban life will undoubtedly become increasingly one-sided as cities expand and occupations become more sedentary. The improvements that our technicians, sanitarians, and city planners have projected for the "world of tomorrow" may meliorate some of these problems,

but they are not likely to eliminate them if our society continues to develop in the pattern of the giant metropolis. We can no more expect engineering devices to give us a healthful environment than we can expect the therapeutic agents of modern medicine to create a healthy individual.

## Decentralization

Without having read any books or articles on human ecology, millions of Americans have sensed the over-all deterioration of modern urban life. They have turned to the suburbs and "exurbs" as a refuge from the burdens of the metropolitan milieu. From all accounts of suburban life, many of these burdens have followed them into the countryside. Suburbanites have not adapted to the land; they have merely adapted a metropolitan manner of life to semi-rural surroundings. The metropolis remains the axis around which their lives turn. It is the source of their livelihood, their food staples, and, in large part, their tensions. The suburbs have branched away from the city, but they still belong to the metropolitan tree. It would be wise, however, to stop ridiculing the exodus to the suburbs and to try to understand what lies behind this phenomenon. The modern city has reached its limits. Megalopolitan life is breaking down-psychically, economically, and biologically. Millions of people have acknowledged this breakdown by "voting with their feet"; they have picked up their belongings and left. If they have not been able to sever their connections with the metropolis, at least they have tried. As a social symptom, the effort is significant. The reconciliation of man with the natural world is no longer merely desirable; it has become a necessity. It is a compelling need that is sending millions of people into the countryside. The need has created a new interest in camping, handicrafts, and horticulture. In ever-increasing numbers, Americans are acquiring a passionate interest in their national parks and forests, in their rural landscape, and in their small-town agrarian heritage.

Despite its many shortcomings, this trend reflects a basically sound orientation. The average American is making an attempt, however confusedly, to reduce his environment to a human scale. He is trying to recreate a world that he can cope with as an individual, a world that he correctly identifies with the freedom, gentler rhythms, and quietude of rural surroundings. His attempts at gardening, landscaping, carpentry, home maintenance, and other so-called suburban "vices" reflect a need to function within an intelligible, manipulatable, and individually creative sphere of human activity. The suburbanite, like the camper, senses that he is working with basic, abiding things that have slipped from his control in the metropolitan world-shelter, the handiwork that enters into daily life, vegetation, and the land. He is fortunate, to be sure, if these activities do not descend to the level of caricature. Nevertheless, they are important, not only because they reflect basic needs of man but because they also reflect basic needs of the things with which he is working. The human scale is also the natural scale. The soil, the land, the living things on which man depends for his nutriment and recreation are direly in need of individual care.

For one thing, proper maintenance of the soil not only depends upon advances in our knowledge of soil chemistry and soil fertility; it also requires a more personalized approach to agriculture. Thus far, the trend has been the other way; agriculture has become depersonalized and over-industrialized. Modern farming is suffering from gigantism. The average agricultural unit is getting so big that the finer aspects of soil performance and soil needs are being overlooked. If differences in the quality and performance of various kinds of soil are to receive more attention, American farming must be reduced to a more human scale. It will become necessary to bring agri-

culture within the scope of the individual, so that the farmer and the soil can develop together, each responding as fully as possible to the needs of the other.

The same is true for the management of livestock. Today our food animals are being manipulated like a lifeless industrial resource. Normally, large numbers of animals are collected in the smallest possible area and are allowed only as much movement as is necessary for mere survival. Our meat animals have been placed on a diet composed for the most part of medicated feed high in carbohydrates. Before they are slaughtered, these obese, rapidly matured creatures seldom spend more than six months on the range and six months on farms, where they are kept on concentrated rations and gain about two pounds daily. Our dairy herds are handled like machines; our poultry flocks, like hothouse tomatoes. The need to restore the time-honored intimacy between man and his livestock is just as pronounced as the need to bring agriculture within the horizon of the individual farmer. Although modern technology has enlarged the elements that enter into the agricultural situation, giving each man a wider area of sovereignty and control, machines have not lessened the importance of personal familiarity with the land, its vegetation, and the living things it supports. Unless principles of good land use permit otherwise, a farm should not become smaller or larger than the individual farmer can command. If it is smaller, agriculture will become inefficient; if larger, it will become depersonalized.

With the decline in the quality of urban life, on the one hand, and the growing imbalance in agriculture, on the other, our times are beginning to witness a remarkable confluence of human interests with the needs of the natural world. Men of the nineteenth century assumed a posture of defiance toward the forests, plains, and mountains. Their applause was reserved for the engineer, the technician, the inventor, at times even the robber baron and the railroader, who seemed to offer the promise of a more abundant material life. Today we are filled with a vague nostalgia for the past. To a large degree this nostalgia reflects the insecurity and uncertainty of our times, in contrast with the echoes of a more optimistic and perhaps more tranquil era. But it also reflects a deep sense of loss, a longing for the free, unblemished land that lay before the eyes of the frontiersman and early settler. We are seeking out the mountains they tried to avoid and we are trying to recover fragments of the forests they removed. Our nostalgia springs neither from a greater sensitivity nor from the wilder depths of human instinct. It springs from a growing need to restore the normal, balanced, and manageable rhythms of human life - that is, an environment that meets our requirements as individuals and biological beings.

Modern man can never return to the primitive life he so often idealizes, but the point is that he doesn't have to. The use of farm machinery as such does not conflict with sound agricultural practices; nor are industry and an urbanized community incompatible with a more agrarian, more natural environment. Ironically, advances in technology itself have largely overcome the industrial problems that once justified the huge concentrations of people and facilities in a few urban areas. Automobiles, aircraft, electric power, and electronic devices have eliminated nearly all the problems of transportation, communication, and social isolation that burdened man in past eras. We can now communicate with one another over a distance of thousands of miles in a matter of seconds, and we can travel to the most remote areas of the world in a few hours. The obstacles created by space and time are essentially gone. Similarly, size need no longer be a problem. Technologists have developed remarkable small-scale alternatives to many of the giant facilities that still dominate modern industry. The smoky steel town, for example, is an anachronism. Excellent steel can be made and rolled with installations that occupy about two or three city blocks. (For example, by using Sendzimir's planetary rolling mill, which reduces a 2 1/4 inch - thick steel

slab to 1/10 of an inch in a single pass through a set of work rolls.. The conventional continuous strip mill involves the use of scale-breaker stands, about four roughening stands, six finishing stands, long roller tables, and other machines -a huge and costly installation.) Many of the latest machines are highly versatile and compact. They lend themselves to a large variety of manufacturing and finishing operations. Today the more modern plant, with its clean, quiet, versatile, and largely automated facilities, contrasts sharply with the huge, ugly, congested factories inherited from an earlier industrial era.

Thus, almost without realizing it, we have been preparing the material conditions for a new type of human community-one which constitutes neither a complete return to the past nor a suburban accommodation to the present. It is no longer fanciful to think of man's future environment in terms of a decentralized, moderate-sized city that combines industry with agriculture, not only in the same civic entity but in the occupational activities of the same individual. The "urbanized farmer" or the "agrarianized townsman" need not be a contradiction in terms. This way of life was achieved for a time by the Greek polis, by early republican Rome, and by the Renaissance commune. The urban centers that became the wellsprings of Western civilization were not strictly cities, in the modern sense of the term. Rather, they brought agriculture together with urban life, synthesizing both into a rounded human, cultural, and social development.

Whether modern man manages to reach this point or travels only part of the way, some kind of decentralization will be necessary to achieve a lasting equilibrium between society and nature. Urban decentralization underlies any hope of achieving ecological control of pest infestations in agriculture. Only a community well integrated with the resources of the surrounding region can promote agricultural and biological diversity. With careful planning, man could use plants and animals not only as a source of food but also, by pitting one species of life against another, as a means of controlling pests, thus eliminating much of his need for chemical methods. What is equally important, a decentralized community holds the greatest promise for conserving natural resources, particularly as it would promote the use of local sources of energy. Instead of relying primarily on concentrated sources of fuel in distant regions of the continent, the community could make maximum use of its own energy resources, such as wind power, solar energy, and hydroelectric power. These sources of energy, so often overlooked because of an almost exclusive reliance on a national division of labor, would help greatly to conserve the remaining supply of high-grade petroleum and coal. They would almost certainly postpone, if not eliminate, the need for turning to radioactive substances and nuclear reactors as major sources of industrial energy. With more time at his disposal for intensive research, man might learn either to employ solar energy and wind power as the principal sources of energy or to eliminate the hazard of radioactive contamination from nuclear reactors.

It is true, of course, that our life lines would become more complex and, from a technological point of view, less "efficient." There would be many duplications of effort. Instead of being concentrated in two or three areas of the country, steel plants would be spread out, with many communities employing small-scale facilities to meet regional or local needs. But the word "efficiency," like the word "pest," is a relative term. Although a duplication of facilities would be somewhat costly, many local mineral sources that are not used today because they are too widely scattered or too small for the purposes of large-scale production, would become economical for the purposes of a smaller community. Thus, in the long run, a more localized or regional form of industrial activity is likely to promote a more efficient use of resources than our prevailing methods of production.

It is true that we will never entirely eliminate the need for a national and international division of labor in agriculture and industry. The Midwest will always remain the best source of our grains; the East and Far West, the best sources of lumber and certain field crops. Our petroleum, high-grade coal, and certain minerals will still have to be supplied, in large part, by a few regions of the country. But there is no reason why we cannot reduce the burden that our national division of labor currently places on these areas by spreading the agricultural and industrial loads over wider areas of the country. This seems to be the only approach to the task of creating a long-range balance between man and the natural world and of remaking man's synthetic environment in a form that will promote human health and fitness.

An emphasis on agriculture and urban regionalism is somewhat disconcerting to the average city dweller. It conjures up an image of cultural isolation and social stagnation, of a journey backward in history to the agrarian societies of the medieval and ancient worlds. Actually the urban dweller today is more isolated in the big city than his ancestors were in the countryside. The city man in the modern metropolis has reached a degree of anonymity, social atomization, and spiritual isolation that is virtually unprecedented in human history. Today man's alienation from man is almost absolute. His standards of co-operation, mutual aid, simple human hospitality, and decency have suffered an appalling amount of erosion in the urban milieu. Man's civic institutions have become cold, impersonal agencies for the manipulation of his destiny, and his culture has increasingly accommodated itself to the least common denominator of intelligence and taste. He has nothing to lose even by a backward glance; indeed, in this way he is likely to place his present-day world and its limitations in a clearer perspective.

But why should an emphasis on agriculture and urban regionalism be regarded as an attempt to return to the past? Can we not develop our environment more selectively, more subtly, and more rationally than we have thus far, combining the best of the past and present and bringing forth a new synthesis of man and nature nation and region, town and country? Life would indeed cease to be an adventure if we merely elaborated the present by extending urban sprawl and by expanding civic life until it completely escapes from the control of its individual human elements. To continue along these lines would serve not to promote social evolution but rather to "fatten" the social organism to a point where it could no longer move. Our purpose should be to make individual life a more rounded experience, and this we can hope to accomplish at the present stage of our development only by restoring the complexity of man's environment and by reducing the community to a human scale.

Is there any evidence that reason will prevail in the management of our affairs? It is difficult to give a direct answer. Certainly we are beginning to look for qualitative improvements in many aspects of life; we are getting weary and resentful of the shoddiness in our goods and services. We are gaining a new appreciation of the land and its problems, and a greater realization of the social promise offered by a more manageable human community. More and more is being written about our synthetic environment, and the criticism is more pointed than it has been in almost half a century. Perhaps we can still hope, as Mumford did more than two decades ago in the closing lines of *The Culture of Cities*:

"We have much to unbuild, and much more to build: but the foundations are ready: the machines are set in place and the tools are bright and keen: the architects, the engineers, and the workmen are assembled. None of us may live to see the complete building, and perhaps in the nature of things the building can never be completed: but some of us will see the flag or the fir tree that the workers will plant aloft in ancient ritual when they cap the topmost story."



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