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SILENT SPRING—III

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Illustration by Emiliano Ponzi

The biologist George Wald once compared his work in an exceedingly specialized field, the visual pigments of the eye, to "a very narrow window through which at a distance one can see only a crack of light" but through which "as one comes closer the view grows wider and wider, until finally through this same narrow window one is looking at the universe." So it is when we turn our attention to the individual cells of living organisms, then to the minute structures within the cells, and, finally, to the molecules within these structures; as we come closer, the view grows wider and wider. Not until quite recently did medical research begin to explore the question of how the individual cell functions in producing the energy that is the indispensable quality of life, though it had long been known that the ultimate work of energy production, or oxidation, is accomplished not in any specialized organ but in every cell of the body. Like a furnace, a living cell burns fuel to produce energy, though the "burning" is accomplished with only the moderate heat of the body's normal temperature. Should all the billions of gently burning little fires cease to burn, the physical chemist Eugene Rabinowitch has said, "no heart could beat, no plant could grow upward defying gravity, no amoeba could swim, no sensation could speed along a nerve, no thought could flash in the human brain." And now this beautifully functioning mechanism is in danger of being disrupted as a result of the activities of man himself, for he has brought into being many radically new substances—not only radioactive dust but chemicals for use against insects, rodents, and weeds—and the nature of some of these substances is such that they may strike directly at this very system.

The transformation of matter in to energy in the cell is a continuous process, one of nature's cycles of renewal, which can be compared to a wheel endlessly turning. Grain by grain, molecule by molecule, fuel, in the form of the carbohydrate glucose, is fed into the cell. In its cyclic passage, the fuel molecule undergoes a series of minute chemical changes. The changes are made in orderly fashion, step by step, every step directed and controlled by an enzyme, and at most of these steps energy is produced and waste products (carbon dioxide and water) are given off. This process by which the cell functions as a chemical factory is one of the wonders of the world. The fact that all the functioning parts are of infinitesimal size adds to the marvel. With few exceptions, cells themselves are minute, visible only with the aid of a microscope. Yet the greater part of the work of oxidation is performed in a far smaller theatre; tiny granules within the cell, called mitochondria, are the "powerhouses" in which most of the energy-producing reactions take place. The energy released during the oxidative cycle is transferred to a molecule containing three phosphate groups—adenosine triphosphate, familiarly spoken of by the biochemists as ATP. Alone among the body's substances, ATP, for reasons that are still not fully understood by biochemists, has the ability to make energy available for the normal functioning of the cell. In the course of the transfer of energy, ATP takes part in another cycle—a cycle within a cycle. As the wheel turns, the molecule loses one of its phosphate groups, becoming a diphosphate molecule, ADP, and at that point it releases energy; then, as the wheel turns further, another phosphate group joins ADP, and the potent ATP is restored. The analogy of the storage battery has been used, with ATP representing the charged, ADP the discharged battery. ATP is the universal currency of energy, found in all organisms, from microbes to man. It furnishes mechanical energy to muscle cells, electrical energy to nerve cells. The sperm cell, the fertilized egg ready for the enormous burst of activity that will transform it into a frog or a bird or a human infant, the cell that must create a hormone—all are supplied with ATP. Some of the energy of ATP is used to maintain the structure and function of the mitochondria, but most of it is immediately sent out into the cytoplasm to provide power for other activities. The position of the mitochondria within each cell is eloquent of their function. They are placed so that energy can be delivered precisely where it is needed. In muscle cells they cluster around contracting fibres; in nerve cells they are found at the junction with another cell, supplying energy for the transfer of impulses; in sperm cells they are concentrated at the point where the propellent tail is joined to the head.

The charging of the battery is closely linked to the oxidative process within the mitochondria, and this linking of processes is known as coupled phosphorylation. Under some conditions the combination may become uncoupled. Then the means is lost for providing energy to the cell in usable form; oxidation continues, but no ATP is produced. The cell has become like a racing engine, generating heat but yielding no power. Then the muscle cannot contract or the impulse race along the nerve pathways. Then the sperm cannot move to its destination; the fertilized egg cannot carry to completion its complex divisions and elaborations The consequences of uncoupling can, indeed, be disastrous for any organism, at any stage of its development, from embryo to adult; in time it can lead to the death of the tissue, then to the death of the organism. What is it that causes uncoupling? Radiation can act as an uncoupler, and the death of cells exposed to radiation is thought by some to be brought about in this way. Moreover, laboratory tests show that a good many chemicals share this power, and the insecticides and weed killers are well represented on the list. The group of chemicals known as phenols have a strong effect on metabolism; that is, through their uncoupling action they have the ability to cause a potentially fatal rise in temperature. The dinitrophenols and pentachlorophenols, among other members of this group, are widely used as herbicides. Another uncoupler among the herbicides is 2,4-D, a derivative of one of the phenols. Of the chlorinated hydrocarbons—the chemicals that, along with the organic phosphates, are now the most commonly used insecticides—DDT has been demonstrated to be an uncoupler, and further study will probably reveal others among this group.

However, uncoupling is not the only way in which the little, quietly burning fires in some or all of the body's billions of cells may be extinguished. We have seen that each step in oxidation is directed and expedited by an enzyme. When one of these enzymes is destroyed or weakened, the cycle of oxidation within the cell comes to a halt. If we thrust a crowbar between the spokes of a wheel, it makes no difference where we do it—the wheel stops turning. In the same way, if we destroy an enzyme that functions at any point in the cycle, oxidation ceases, and there is no further production of energy. The crowbar can be supplied by any of a number of chemicals commonly used as pesticides. DDT, methoxychlor, malathion, phenothiazine, and various dinitro compounds are among the pesticides that have been found to inhibit one or more of the enzymes concerned in the cycle of oxidation. They thus appear as agents potentially capable of blocking the whole process of energy production and depriving the cells of utilizable oxygen. This is an injury with disastrous consequences. By intermittently withholding oxygen from tissue cultures, Dr. Harry Goldblatt, in experiments conducted at the Institute of Medical Research of Cedars of Lebanon Hospital, in Los Angeles, has caused normal cells to turn into cancer cells. Other effects have been observed in experiments on animal embryos. Without sufficient oxygen, the orderly processes by which the tissues unfold and the organs develop is disrupted; malformations and other abnormalities then occur. The evidence of this from animal experiments is overwhelming, and there is good reason to believe that the human embryo that is deprived of adequate oxygen may also develop deformities. There are signs of an increase in such disasters, though few people look far enough to find all the causes. In one of the more unpleasant portents of the times, the Office of Vital Statistics in 1961 initiated a national tabulation of congenital malformations, with the explanatory comment that these statistics would provide needed data about the incidence of such malformations and the circumstances under which they occur. Studies of this sort will no doubt be directed largely toward measuring the effects of radiation, but it must be remembered that many chemicals produce precisely the same effects. Some of the defects and malformations in tomorrow's children will almost certainly be caused by these chemicals, which now permeate our outer and inner worlds.

It may well be that certain recent findings about diminished reproduction in birds can also be related to interference with biological oxidation, and a consequent depletion of ATP. The egg, even before fertilization, needs to be generously supplied with ATP, in preparation for the enormous effort that will be required once fertilization has occurred. Whether the sperm cell will reach and penetrate the egg depends upon its own supply of ATP, generated in those mitochondria so thickly clustered in the neck of the cell. And once fertilization is accomplished and cell division has begun, the supply of energy in the form of ATP will determine whether the development of the embryo will proceed.

Embryologists studying some of their most convenient subjects, the fertilized eggs of frogs and of sea urchins, have found that if the ATP content in one of these eggs falls below a certain critical level, the egg simply stops dividing and soon dies. It is only a step from the embryology laboratory to the apple tree where a robin's nest holds its complement of blue-green eggs—but eggs that lie cold, the fires of life that flickered for a few days now extinguished. Why did the robins not hatch? Did the eggs of the birds stop developing simply because they lacked enough ATP molecules? And was the lack of ATP the result of the fact that in the bodies of the parent birds and in the eggs themselves there were stored enough insecticides to stop the little turning wheels of oxidation? It is no longer necessary to guess about the storage of insecticides in birds' eggs, which obviously lend themselves to this kind of observation more readily than the mammalian ovum. Whenever researchers have examined the eggs of birds that have been exposed to DDT and other chlorinated hydrocarbons, either experimentally or in the wild, they have found residues of the chemicals. And the concentrations have been heavy. In a California experiment, pheasants that were fed a diet containing forty-two parts per million of a chlorinated hydrocarbon called dieldrin—commonly used in the spraying of lawns—laid eggs containing up to a hundred and ninety-three parts per million of the chemical. In Michigan, eggs taken from the oviducts of robins dead of DDT poisoning showed concentrations of up to two hundred parts per million. Other eggs were taken from nests that had been left unattended when the parent robins were stricken with poison; these, too, contained DDT. Chickens poisoned by aldrin—an even deadlier hydrocarbon—passed the chemical on to their eggs. Hens that were experimentally fed DDT laid eggs containing as much as sixty-five parts per million.

The fact that insecticide is stored in the germ cells of any species should disturb us, suggesting comparable effects in human beings. Moreover, there are indications that these chemicals lodge not only in the germ cells themselves but in tissues concerned with the manufacture of these cells. Accumulations of insecticides have been discovered in the gonads of a variety of birds and mammals exposed to the chemicals in laboratories and in sprayed fields and forests—robins, pheasants, mice, guinea pigs, deer. In one male robin, DDT was concentrated more heavily in the testes than in any other part of the body. Pheasants also accumulated extraordinary amounts of DDT in the testes—up to fifteen hundred parts per million. Probably as an effect of such storage in the sex organs, atrophy of the testes has been observed in experimental mammals. Young rats exposed to methoxychlor had extraordinarily small testes. When young roosters were fed DDT, the testes achieved only eighteen per cent of their normal growth, and the birds' combs and wattles, being dependent for their development upon the testicular hormone, were only a third the normal size. The spermatozoa, too, may well be affected by the storage of chemicals. Experiments show that the motility of bull sperm is decreased by dinitrophenol. And some indication of the possible effect on human beings is seen in medical reports of oligospermia, or reduced production of spermatozoa, among the pilots of planes used for dusting crops with DDT.

For mankind as a whole, a possession infinitely more valuable than individual life is our genetic heritage, our link with past and future. Shaped through aeons of evolution, our genes not only make us what we are but hold in their minute beings the promise, or threat, of what we shall become. Yet genetic deterioration as a result of man's own handiwork is the menace of our time. The Australian virologist Sir Macfarlane Burnet, who won the Nobel Prize in

1960 for his work in immunology, has described "active and avoidable genetic deterioration" as "the last and greatest danger to our civilization." Again, the parallel between chemicals and radiation is exact and unmistakable. The living cell assaulted by radiation may suffer various kinds of injuries: its ability to divide normally may be destroyed; the structure of its chromosomes may be altered; its genes, carriers of hereditary material, may undergo those sudden, irreversible changes known as mutations, which cause them to produce new characteristics in succeeding generations; or, if the cell is especially susceptible, it may be killed outright, or else, after a lapse of time measured in years, it may become malignant. All these consequences of radiation have been duplicated in laboratory studies by a large group of chemicals, which are therefore known as radiomimetic, or radiation-imitating. These include many chemicals used as insecticides and herbicides.

Only a few decades ago, no one knew about these effects of either radiation or chemicals. Then, in 1927, a professor of zoology at the University of Texas, H. J. Muller, found that by exposing an organism to X-rays he could produce mutations in succeeding generations. With this discovery, a vast new field of knowledge was opened up. Muller later received the Nobel Prize for Medicine in honor of his achievement, and today, in a world that has gained unhappy familiarity with the gray rains of fallout, even the nonscientist knows the potential results of radiation. Far less notice has been taken of a companion discovery, made by Charlotte Auerbach and William Robson at the University of Edinburgh in the early nineteen-forties. Working with mustard gas, they found that this chemical produces permanent chromosome abnormalities that cannot be distinguished from those produced by radiation. Tested on the fruit fly—the classic subject of genetic experiments—mustard gas also produced mutations. Thus the first chemical mutagen was discovered. Mustard gas has now been joined by a long list of other chemicals known to alter genetic material in plants and animals.

To understand how these chemicals can change the course of heredity, one must first watch the basic drama of life as it is played on the stage of the living cell. If the body is to grow and if the stream of life is to be kept flowing from generation to generation, the cells composing the tissues and organs of the body must have the power to increase in number. This increase is ordinarily accomplished by the process called mitosis, or nuclear division. In a cell that is about to divide, changes of the utmost importance occur. Within the nucleus, the chromosomes mysteriously move and divide, ranging themselves in patterns that will serve to distribute the determiners of heredity, the genes, to the daughter cells. First, the chromosomes assume the form of elongated threads, on which the genes are aligned like beads on a string. Then each chromosome divides lengthwise, and each gene divides, too, so that when the cell itself divides, each of the new cells will contain a complete set of chromosomes, and hence all the genetic information encoded within them. In this way, the integrity of the race and of the species is preserved. In this way, like begets like. A special kind of cell division, called meiosis, occurs in the formation of the germ cells. Because the number of chromosomes for a given species is constant, the egg and the sperm, which are to unite to form a new individual, must carry to their union only half the species number. This is accomplished with extraordinary precision by a change that occurs in the behavior of the chromosomes during one of the divisions that produce those cells. At this time, the chromosomes do not split; instead, whole chromosomes go into each daughter cell.

In the elemental drama of cell division, all life is revealed as one. Cell division is common to all earthly life; neither man nor amoeba, the giant sequoia nor the simple yeast cell can long exist without carrying on this process. “The major features of cellular organization, including, for instance, mitosis, must be much older than five hundred million years—more nearly a thousand million,” wrote George Gaylord Simpson and his colleagues Colin S. Pittendrigh and Lewis H. Tiffany in their book entitled “Life.” “In this sense the world of life, while surely fragile and complex, is incredibly durable through time—more durable than mountains. This durability is wholly dependent on the almost incredible accuracy with which the inherited information is copied from generation to generation.”

In all the thousand million years envisioned by these men, no threat has struck so directly and so forcefully at that “incredible accuracy” as the mid-twentieth-century threat of man-made radiation and man-made chemicals. Sir Macfarlane Burnet considers it “one of the most significant medical features” of our time that “as a by-product of more and more powerful therapeutic procedures and the production of chemical substances outside of biological experiences, the normal protective barriers that kept mutagenic agents from the internal organs have been more and more frequently penetrated.” Because the study of human chromosomes is itself in its infancy, it has only recently become possible to study the effect of environmental factors upon them. Not until 1956 did new techniques make it possible to determine accurately the number of chromosomes in the human cell—forty-six—and to observe them in such detail that the presence or absence of single chromosomes, or parts of chromosomes, could be detected. The whole concept of genetic damage as a result of something in the environment is also relatively new, and is little understood except by the geneticists, whose advice is very seldom sought when any alteration of the environment is in prospect. The hazard from radiation in its various forms is now generally recognized—though it is still denied in surprising places. Dr. Muller has had occasion to deplore “the resistance to the acceptance of genetic principles on the part of so many, not only of governmental appointees in the policy-making positions, but also of so many of the medical profession.” He warns that various chemicals, including groups represented by pesticides, “can raise the mutation frequency as much as radiation,” and he says, “As yet far too little is known of the extent to which our genes, under modern conditions of exposure to unusual chemicals, are being subjected to such mutagenic influences.”

Although the study of chemical mutagens is widely neglected, it is possible to assemble specific information on the effects that a number of pesticides have on the living cells of certain plants and insects. When several generations of mosquitoes were exposed to DDT, for instance, strange creatures called gynandromorphs—part male and part female—resulted. Plants treated with various phenols suffered profound damage to their chromosomes, changes in genes, and a striking number of mutations. Mutations also occurred in fruit flies that were subjected to phenol, and on exposure to a common herbicide—a sodium salt of one of the phthalic acids—or to urethane, these flies developed mutations so damaging as to be fatal. Urethane belongs to a group of chemicals called carbamates, from which an increasing number of insecticides and other agricultural chemicals are drawn. Two of the carbamates are used to prevent potatoes from sprouting in storage, because of their proved effect in stopping cell division. One of these, maleic hydrazide, is rated a powerful mutagen. Plants treated with the chlorinated hydrocarbon BHC (henzene hexachloride) or with an isomer of BHC called lindane became monstrously deformed, with tumorlike swellings on their roots. Their cells became swollen with chromosomes, which doubled in number. The doubling continued in future cell divisions until further division was mechanically impossible. The herbicide 2,4-D has also produced tumorlike swellings in treated plants. In such plants, the chromosomes become short, thick, and clumped together, and cell division is seriously retarded. The general effect is said to parallel closely the effect produced by X-rays. And these are but a few of many illustrations that could be cited. As yet, however, there has been no comprehensive study aimed at testing the mutagenic effects of pesticides as such. The facts noted above are by-products of research in cell physiology or in genetics. A direct attack on the problem is urgently needed.

What chromosome abnormalities can mean to man has been the subject of an immense amount of recent research, conducted in many countries. In 1959, several British and French research teams discovered that their independent studies pointed to a common conclusion—that some of humanity's ills are caused by a disturbance of the normal chromosome number. For example, it is now known that all typical mongoloids have one extra chromosome. Occasionally, this is attached to another, so that the chromosome number remains the normal forty-six. As a rule, however, the extra chromosome is separate, making the number forty-seven. In such individuals, the original cause of the defect must have occurred in the generation preceding its appearance. A different mechanism seems to have operated in some patients, both in America and in Great Britain, who suffered from a chronic form of leukemia. They were found to have a consistent chromosome abnormality in certain blood cells, the abnormality in this case consisting of the loss of part of a chromosome. In these patients, the skin cells had the normal complement of chromosomes, indicating that the chromosome defect did not originate in the parents' germ cells but, rather, represented damage to the blood-forming tissues during the life of the patients.

The list of defects linked to chromosome disturbances has grown with surprising speed since the opening up of this territory. One defect, known as Klinefelter's syndrome, involves a duplication of one of the sex chromosomes. Normally, the cells of any male creature contain one X, or female, sex chromosome and one Y, or male, chromosome, and the cells of a female contain two X chromosomes. In Klinefelter's syndrome, the Y chromosome is present but the X chromosome is duplicated. The resulting individual is a male, but because he carries two of the X chromosomes he is somewhat abnormal, and is sterile. Excessive height and various mental defects often accompany this condition, for, of course, each chromosome carries genes for a variety of characteristics. In contrast, an individual who receives only one sex chromosome—the X chromosome—and thus has a complement of XO instead of either XX or XY, is actually female but lacks many secondary sexual characteristics. Again, the condition is accompanied by physical abnormalities and sometimes by mental defects. This is known as Turner's syndrome. Both conditions had been described in medical literature long before the cause was known.

Some extremely significant work is now being done at the University of Wisconsin, where a group of researchers, headed by Dr. Klaus Patau, has been studying a variety of congenital abnormalities that seem to result from the duplication of only part of a chromosome—a situation suggesting that somewhere in the formation of one of the germ cells a chromosome has broken and the pieces have not been properly redistributed. All the conditions that have so far been described by Dr. Patau and his associates involve serious defects in development, and most of them involve mental retardation.

This is such a new field of study that up to now scientists have concentrated on identifying the chromosome abnormalities associated with disease and defective development, rather than on speculating about their causes. It would be foolish to assume that any single agent is responsible for damaging chromosomes or causing them to behave erratically during cell division. Some scientists who are willing to concede the potent effect of environmental radiation on man nevertheless question whether mutagenic chemicals can, as a practical proposition, have the same effect; they point out that radiation has great penetrating power, and doubt whether chemicals can reach the germ cells. However, as we have seen, there is strong evidence from observation of animals that the chlorinated hydrocarbons do reach the gonads and are stored there, or in the germ cells themselves. At least one chemical—not a pesticide—has been found to halt cell division in the gonads of birds. Obviously, then, there is little basis for the belief that the gonads of any organism are shielded from chemicals. Once again we are hampered by the fact that there has been little direct investigation of the problem in man. But if there is any doubt at all, can we afford to pour chemicals into the environment that have the power to strike directly at the chromosomes? Is this not too high a price to pay for a sproutless potato or a mosquitoless patio? We can, if we wish, reduce this threat to our genetic heritage, a possession that has come down to us through some two billion years of evolution and selection of living protoplasm, and that is ours for the moment only, until we pass it on to the generation to come. We are doing little now to preserve its integrity. Although manufacturers of chemicals are required by law to test their materials for toxicity, they are not required to make the tests that would reliably demonstrate genetic effects, and they do not do so.

As the tide of chemicals born of the Industrial Age has risen to engulf our environment, a drastic change has come about in the nature of our most serious public-health problems. Only yesterday, mankind lived in fear of smallpox, cholera, and plague—scourges that swept nations before them. Now our major concern has ceased to be these and other disease organisms, which were once omnipresent; sanitation, better living conditions, and new drugs have given us a high degree of control over infectious disease. We are concerned today with a different kind of hazard that lurks in our environment—a hazard that we ourselves have contributed to. The presence of radioactive particles and man-made chemicals in the world casts a shadow that is no less ominous because it is formless and obscure, no less frightening because it is simply impossible at the moment to predict the effects of lifetime exposure to chemical and physical agents that are not part of the biological experience of man. "We all live under the shadow of a haunting fear that something may corrupt the environment to the point where man joins the dinosaurs as an obsolete form of life," Dr. David E. Price, of the United States Public Health Service, has said. "And what makes these thoughts all the more disturbing is the knowledge that our fate could perhaps be sealed twenty or more years before the development of symptoms."

Where do pesticides fit into the picture of environmental disease? They now contaminate soil, water, and food, and they have the power to make our streams fishless and our gardens and woodlands silent and birdless. Man, however much he may like to pretend the contrary, is part of nature. Can he escape a pollution that is now so thoroughly distributed throughout his world? We know that even single exposures to these chemicals can, if the amount is large enough, precipitate acute poisoning. But this is not the major problem. The sudden illness or death of farmers, spraymen, pilots, and others exposed to appreciable quantities of pesticides are tragic. For the population as a whole, however, we must be more concerned with the delayed effects of absorbing repeated small amounts of the pesticides that invisibly contaminate our world.

Responsible public-health officials have pointed out that since the biological effects of chemicals are cumulative over long periods, the hazard to the individual may depend on the sum of the exposures he receives throughout his lifetime. For these very reasons, the danger is easily ignored. It is human nature to shrug off what seems a vague threat of future disaster. "Men are naturally most impressed by diseases which have obvious manifestations," says a wise physician, Dr. René Dubos, of the Rockefeller Institute, "yet some of their worst enemies creep on them unobtrusively." For each of us, this is a problem of interrelationships, of interdependence—essentially, of ecology. We poison the caddis flies in a stream, and the salmon runs dwindle and die. We poison the gnats in a lake, and the poison travels from link to link of the food chain, and soon the birds of the lake margin become its victims. We spray our elms, and the following springs are silent, empty of robin song, not because we attacked the robins directly but because the poison travelled, step by step, through the now familiar cycle of elm leaf to earthworm to robin. These are matters of record and an observable part of the visible world around us. But there is also an ecology of the world within our bodies. In this unseen world, minute causes produce mighty effects; the effect, moreover, often seems to have no connection with the cause, appearing in a part of the body remote from the area where the original injury was sustained. "A change at one point, in one molecule even, may reverberate throughout the entire system to initiate changes in seemingly unrelated organs and tissues," says a recent summary of the current status of medical research carried out by the American Foundation, an independent research organization. When one is concerned with the mysterious and wonderful functioning of the human body, then, discovering the agent of disease and death depends on a piecing together of many apparently disparate facts established in the course of a vast amount of research in widely separated fields. Research men have always been handicapped by the inadequacy of known means of detecting the beginnings of injury; indeed, lack of sufficiently delicate methods of detecting such beginnings is one of the great unsolved problems in medicine.

"I know that dieldrin has caused convulsions among spraymen," someone may say, "but I have used dieldrin sprays on the lawn many times, and I have never had convulsions, so it hasn't harmed me." It is not as simple as that. Despite the absence of sudden and dramatic symptoms, anyone who handles such materials is unquestionably storing up toxic materials in his body. The chlorinated hydrocarbons accumulate in all the fatty tissues. When these reserves of fat are drawn upon, the poison may strike quickly. A New Zealand medical journal recently provided an example. A man under treatment for obesity suddenly developed symptoms of poisoning; on examination, his fat was found to contain stored dieldrin, which had been metabolized as he lost weight. The same thing could happen with loss of weight in illness. Or the results of storage could be far less obvious. Several years ago, the *Journal* of the American Medical Association issued a strong warning about the hazards of insecticide storage in adipose tissue, pointing out that drugs or chemicals that accumulate in this manner must be handled with greater caution than others. The adipose tissue, we were warned, is not merely a place for the deposition of fat (which ordinarily makes up about eighteen per cent of the body weight) but has many other important functions, which the stored poisons may interfere with. Furthermore, fats are distributed throughout the organs and tissues of the whole body, being present even in cell membranes; thus the insecticides are stored in individual cells, where they are in a position to interfere with those vital functions of oxidation and energy production.

One of the most significant effects exerted by the chlorinated-hydrocarbon insecticides is concerned with the liver. Of all the organs in the body, the liver is perhaps the most extraordinary. In its versatility in performing a large number of indispensable functions, it has no equal; in fact, it presides over so many such activities that even the slightest damage to it has serious consequences. It provides bile for the digestion of fats, and, in addition, because of its position in the body, and the special circulatory pathways that converge on it, it receives blood directly from the digestive tract and is deeply involved in the metabolism of all the principal foodstuffs. It stores sugar, in the form of glycogen, and releases it, in the form of glucose, in carefully measured quantities, to keep the blood sugar at a normal level. It builds body proteins, including some essential elements of blood plasma, concerned with blood clotting. It maintains cholesterol at its proper level in the blood plasma, and inactivates the male and female hormones when imbalance threatens. It is a storehouse of many vitamins, some of which, in turn, contribute to its own functioning. Moreover, it defends the body against the great variety of poisons that continually invade it. Some of these are normal by-products of metabolism, which the liver swiftly and efficiently renders harmless. But poisons that have no normal place in the body may also be detoxicated. For example, the "harmless" insecticides malathion and methoxychlor are less poisonous than their relatives only because a liver enzyme deals with them, altering their molecules in such a manner that their capacity for harm is lessened. In similar ways, the liver deals with the majority of the toxic materials to which we are exposed.

Now, however, our line of defense against both poisons from within and poisons from without is weakened and crumbling, for it is known that the chlorinated hydrocarbons can damage the liver. Not only is a damaged liver incapable of protecting us from poisons; the whole wide range of its activities may be interfered with. Far-reaching though the consequences are, their very variety, together with the fact that they do not always immediately follow exposure, means that they may fail to be related to their true cause. In view of the nearly universal use of insecticides that are liver poisons, it is noteworthy that a sharp rise in hepatitis began during the nineteen-fifties and is continuing a fluctuating climb. While it is admittedly difficult, in dealing with a human being, rather than a laboratory animal, to "prove" that Cause A produces Effect B, plain common sense suggests that the relation between a soaring rate of liver disease and the prevalence of liver poisons in the environment is no coincidence. Whether or not the chlorinated hydrocarbons are the primary cause, it seems hardly sensible, under the circumstances, for us to expose ourselves to poisons that have a proved ability to damage the liver, and so, presumably, to make it less resistant to disease.

Both major types of insecticides, the chlorinated hydrocarbons and the organic phosphates, directly affect the nervous system, though in somewhat different ways. This has been made clear by an infinite number of experiments on animals and by observation of human subjects as well. To begin with DDT, its action in man is primarily on the central nervous system; the cerebellum and the higher motor cortex are thought to be the areas chiefly affected. According to a standard textbook of toxicology, abnormal sensations, as of prickling, burning, and itching, along with tremors and even convulsions, may follow exposure to appreciable amounts. Our first knowledge of the symptoms of acute poisoning by DDT was furnished by several British investigators, who deliberately exposed themselves in order to learn the consequences. In 1945, two scientists at the British Royal Naval Physiological Laboratory invited absorption of DDT through the skin by sitting or lying against walls covered with a water-soluble paint containing a two-per-cent concentration of DDT overlaid with a thin film of oil. The direct effect of DDT on the nervous system is apparent in their eloquent description of their symptoms: "The tiredness, heaviness, and aching of the limbs were very real things, and the mental state also was most distressing. . . . [There was] extreme irritability . . . great distaste for work of any sort . . . a feeling of mental incompetence in tackling the simplest mental task. . . . The joint pains were quite violent at times." Another early British experimenter, who systematically applied DDT in acetone solution to his hands, reported heaviness and aching of the limbs, muscular weakness, and "spasms of extreme nervous tension." He took a holiday and improved, but when he returned to work his condition deteriorated. He then spent three weeks in bed, made miserable by constant aching of the limbs, insomnia, nervous tension, and feelings of acute anxiety. On occasion, tremors shook his whole body—tremors of a sort that have since become all too familiar through the sight of birds poisoned by DDT. The experimenter was away from his work for ten weeks, and at the end of a year, when his case was reported in a British medical journal, his recovery was not complete.

Although many doctors have been slow to recognize the hazards of pesticides, there are now many cases on record in which both the symptoms and the whole course of the illness point to them as the cause. Typically, such a victim has had a known exposure to one of the insecticides, and his symptoms have subsided under treatment, which has included the banishing of all insecticides from his environment, but, most significantly, they have returned after each renewed contact with the offending chemicals. This sort of evidence, and no more, forms the basis of a vast amount of medical therapy concerned with disorders in other fields. The method of diagnosis used by the allergists is to expose the patient to a suspected allergen. If a reaction occurs, the allergen is incriminated without hesitation. Or if a patient, on being treated with a drug, develops an adverse reaction, use of the drug is ordinarily discontinued on the assumption that it is the cause of the symptom. Why, then, should there be reluctance to incriminate pesticides under parallel circumstances?

Not everyone who handles and uses insecticides develops the same symptoms, for here the matter of individual sensitivity enters in. There is some evidence that women are more susceptible than men, very young children more than adults, those who lead sedentary, indoor lives more than those who lead a rugged life of work or exercise in the open. Beyond these differences are others, no less real because they are intangible. What makes one person allergic to dust or pollen, sensitive to a poison, or susceptible to an infection while another is not is a medical mystery. The situation nevertheless exists, and it affects significant numbers of the population. Some physicians estimate that a third or more of their patients show signs of some form of sensitivity, and that the number is growing. And, unfortunately, sensitivity to a substance may suddenly develop in a person who has previously been insensitive to it; in fact, some medical men believe that intermittent exposures to chemicals may produce just such sensitivity.

The whole problem of pesticide poisoning is enormously complicated by the fact that a human being, unlike a laboratory animal living under rigidly controlled conditions, is never exposed to one chemical alone. Between the various insecticides, and between them and other chemicals, there are interactions that have serious potentials. Whether they are released into the soil or into water or into a man's blood, these unrelated chemicals do not remain segregated; there are interactions by which one alters the power of another for harm. There is such interaction even between the two major groups of insecticides, though they are usually thought to be completely distinct in their action. The organic phosphates alone, because they poison the nerve-protective enzyme cholinesterase, may produce symptoms ranging from dizziness and blurred vision to convulsions and coma, often with fatal results. Even an exposure that would normally be too small to produce symptoms may do so if the body has first been exposed to a chlorinated hydrocarbon, which injures the liver. This is because the cholinesterase level may drop below normal when liver function is disturbed. The additional depressive effect of the organic phosphate may then be enough to precipitate acute symptoms. Pairs of the organic phosphates themselves may interact in such a way as to increase their toxicity a hundredfold. And the organic phosphates may interact with various drugs, with food additives, and with who can say how many more of the infinite numbers of man-made substances that now pervade our world?

Furthermore, the effect of a supposedly innocuous chemical can be drastically changed by the action of another chemical, as happens with methoxychlor, a close relative of DDT. Because methoxychlor is not stored to any great extent when it is given alone, we are told that it is a safe chemical. But this is not necessarily true. If the liver has been damaged by another agent, methoxychlor may be stored in the body at a hundred times its normal rate and will then imitate the effects of DDT producing long-lasting effects on the nervous system. Yet the liver damage that brings this about may be so slight as to have passed unnoticed up to that time. It may have resulted from any of a number of commonplace situations—using another insecticide, using a cleaning fluid that contained carbon tetrachloride, or taking one of the so-called tranquillizing drugs, a number (but not all) of which are chlorinated hydrocarbons and possess power to interfere with liver function.

The damage done to the nervous system by chemicals in the environment is not confined to acute poisoning; there may also be delayed effects. Lasting damage to the brain and to the nerves has been reported for methoxychlor and others. Dieldrin, besides its immediate consequences, can have long-delayed consequences ranging from "loss of memory, insomnia, and nightmares to mania," as an official of the Public Health Service wrote in 1959. Lindane, medical findings have shown, is stored in significant amounts in the brain and in functioning liver tissue, and may induce "profound and long-lasting effects on the central nervous system." Yet this chemical is much used in vaporizers—devices that pour a stream of volatilized insecticide into homes, offices, and restaurants. The organic phosphates, which are usually considered only in relation to their more violent manifestations in acute poisoning, also have: the power to cause lasting physical damage to nerve tissues and, according to recent findings, to induce mental disorders. Various cases of delayed paralysis have followed the use of one or another of these insecticides. A bizarre occurrence in the United States around 1930 was an omen of things to come. It was caused not by an insecticide but by a substance belonging chemically to the same group as the organic-phosphate insecticides. During the prohibition era, some medicinal substances were pressed into service as substitutes for liquor, since they were exempt from the prohibition law. One of these was Jamaica ginger. But because the United States Pharmacopoeia product was expensive, bootleggers conceived the idea of making a substitute Jamaica ginger. They succeeded so well that their spurious product responded to the appropriate chemical tests and deceived the government chemists. To give their false ginger the necessary tang, however, they had introduced a chemical called triorthocresyl phosphate, which, like the other organic phosphates, including the well-known parathion, destroys the protective enzyme cholinesterase. As a consequence of drinking the bootleggers' product, some fifteen thousand people developed a permanently crippling type of paralysis of the leg muscles, a condition that became known as "ginger paralysis." The paralysis was accompanied by damage to the sheaths of the nerve fibres and by degeneration of the cells of the anterior horns of the spinal cord.

About two decades later, as various organic phosphates came into use as insecticides, cases reminiscent of the ginger-paralysis episode began to occur. For example, a greenhouse worker in Germany who had been using parathion and had experienced mild symptoms of poisoning on a few such occasions suddenly became paralyzed several months afterward. Then a group of three workers in a chemical factory developed acute poisoning from exposure to insecticides of this group. They recovered under treatment, but ten days later two of them developed muscular weakness in the legs. This persisted for ten months in one, a thirty-nine-year-old man; the other, a twenty-eight-year-old woman, was more severely affected, with paralysis in both legs and some involvement of the hands and arms. Two years later, when her case was reported in a medical journal, she was still unable to walk. The insecticide responsible for these cases has been withdrawn from the market, but some insecticides that are now in use may be capable of like harm. Both malathion (beloved of gardeners) and another organic phosphate, a phenolic compound used as an insecticide, have induced severe muscular weakness in experiments on chickens, and this was attended by destruction of the sheaths of the sciatic and spinal nerves.

All these consequences of organic-phosphate poisoning may be a prelude to something even worse. In view of the severe damage that insecticides of this group inflict upon the nervous system, it was perhaps inevitable that they should eventually be linked with mental disease. In any event, that link has recently been supplied, by investigators at the University of Melbourne and Prince Henry's Hospital, in Melbourne, who reported on sixteen cases of mental disease. All the patients had a history of prolonged exposure to organic-phosphate insecticides. Three were scientists who had checked the efficacy of sprays; eight had worked in greenhouses; five had been farm workers. Their symptoms ranged from impairment of memory to schizophrenic and depressive reactions. Echoes of this sort of thing are to be found widely scattered through medical literature, involving sometimes the chlorinated hydrocarbons, sometimes the organic phosphates. Confusion, delusions, loss of memory, manias—these are a heavy price to pay for the temporary destruction of a few insects, but they are a price that will continue to be exacted as long as we insist on using chemicals that strike directly at the nervous system.

The battle of living things against cancer began so long ago that its beginnings are lost in time. But it unquestionably began in a natural environment, in which whatever life inhabited the earth was subjected, for good or ill, to influences that had their origin in sun and storm and the ancient substances of the planet. Some of the elements of this environment created hazards, to which life had to adjust or perish. The ultraviolet radiation in sunlight could cause malignancy. So could radiations from certain rocks, and so could arsenic washed out of soil or rocks to contaminate food or water supplies. The environment contained these hostile elements even before life began. Yet life arose, and, over millions of years, it came to exist in infinite numbers and endless variety. The natural cancer-causing agents are still a factor in producing malignancy; however, they are few in number, and they belong to that ancient array of forces with which life has had to struggle from the beginning. It was with the advent of man that the situation began to change, for man, alone of all forms of life, can create substances that cause cancer. A few man-made carcinogens (the medical term for all cancer-causing substances) have been part of our environment for centuries; an example is soot. With the dawn of the Industrial Age, the world became a place of continuous and ever-accelerating change. The natural environment was rapidly replaced by an artificial one, composed of new chemical and physical agents, many of which possessed powerful capacities for inducing biological change. Against the carcinogens that his own activities have created, man has no protection, for even as his biological heritage has evolved slowly, so it adapts slowly to new conditions.

The first awareness that external, or environmental, agents could produce cancer dawned in the mind of a London physician nearly two centuries ago. In 1775, Percivall Pott declared that scrotal cancer, then common among chimney sweeps, must be caused by the soot that accumulated on their bodies. He could not furnish the proof that we would demand today, but modern research methods have now isolated the deadly chemicals in soot. For a century or more after Pott's discovery, there seems to have been little further realization that certain chemicals in the human environment could cause cancer, by repeated skin contact, inhalation, or swallowing. True, it had been noticed that skin cancer was prevalent among workers exposed to arsenic fumes in the copper smelters and tin foundries in Cornwall and Wales. And it was realized that workers in the cobalt mines in Saxony and in the uranium mines at Joachimsthal, in Bohemia, were subject to a disease of the lungs, which was later identified as cancer. But these were phenomena of the pre-industrial era. The earliest recognition of malignancies traceable to the Age of Industry came during the last quarter of the nineteenth century. At about the time Pasteur was demonstrating the microbial origin of many infectious diseases, other men were discovering the chemical origin of certain cancers—skin cancers among workers in the new lignite industry in Saxony, and in the Scottish shale industry, and various cancers caused by exposure to tar and pitch.

By the end of the nineteenth century, a half-dozen industrial carcinogens were known; the twentieth century was to create countless new cancer-causing chemicals. In the less than two centuries since the pioneering work of Pott, the environmental situation has changed greatly. No longer are exposures to dangerous chemicals occupational alone; such chemicals have entered the environment of almost everyone—probably even of children still unborn. It is hardly surprising, therefore, that there has lately been an alarming increase in malignant disease. The Monthly Report of the Office of Vital Statistics for July, 1959, states that malignant growths, including those of the lymphatic and blood-forming tissues, accounted for fifteen per cent of the deaths in 1958, compared to only four per cent in 1900. On the basis of the present incidence of the disease, the American Cancer Society estimates that forty-five million Americans now living will eventually develop cancer; this means that malignant disease will strike two out of three families.

The situation with respect to children is even more deeply disturbing. A quarter of a century ago, cancer in children was considered a medical rarity. Then it became more frequent, and in 1947 the first clinic in the United States devoted exclusively to the treatment of children with cancer was established in Boston. Today, more American schoolchildren die of cancer than of any other cause except accidents. Twelve per cent of all the deaths of children between the ages of one and fourteen are caused by cancer. Large numbers of malignant tumors are discovered clinically in children under the age of five, but an even grimmer fact is that significant numbers of such growths are present at or before birth. Dr. W. C. Hueper, chief of the environmental-cancer section of the National Cancer Institute, who is one of the foremost authorities on his subject, has suggested that congenital cancers and cancers in infants may arise from carcinogens to which the mother has been exposed during pregnancy and which penetrate the placenta to act on the rapidly developing fetal tissues. Experiments show that the younger an animal is when it is subjected to a carcinogen, the more likely cancer is to appear. Dr. Francis E. Ray, of the University of Florida, has warned that "we may be initiating cancer in the children of today by the addition of chemicals," and that "we will not know, perhaps for a generation or two, what the effects will be."

Evidence gained from animal experiments has established that several of the pesticides must definitely be rated as carcinogens. As for their effect on human beings, the evidence is circumstantial, as it must be, since we do not use human beings in laboratory experiments involving cancer, but it is nonetheless impressive. The list of carcinogenic chemicals is greatly lengthened if we add those which are believed by some physicians to cause leukemia. Some pesticides may cause cancer not because the chemicals in themselves are carcinogenic but because the petroleum distillates in which they are dissolved or suspended may be carcinogenic. Still other chemicals will be added to the list if we include those whose action on living tissues or cells may be considered an indirect cause of malignancy. One of the pesticides that have been longest associated with cancer is arsenic, occurring in sodium arsenite, which is used as a weed killer, and in calcium arsenate and lead arsenate, which are used as insecticides. A striking example of the consequences of exposure is related by Dr. Hueper in his "Occupational Tumors and Allied Diseases," a classic monograph on the subject. The town of Reichenstein, in Silesia, was for several hundred years the site of arsenic mines, and arsenic wastes accumulated in the vicinity of the mine shafts and were picked up by streams coming down from the nearby mountains.

The underground water became contaminated, and arsenic entered the drinking water. For centuries, many of the inhabitants of the area suffered from what came to be known as "the Reichenstein disease"—chronic arsenicism with accompanying disorders of the liver, the skin, and the gastrointestinal and nervous systems. Malignant tumors were a common accompaniment of the disease. Reichenstein's disease is now chiefly of historical interest, for a quarter of a century ago new water supplies were provided, from which arsenic was largely eliminated. In Córdoba Province, in Argentina, on the other hand, chronic arsenical poisoning, accompanied by skin cancers, is endemic, because the drinking water is contaminated by rock formations containing arsenic. It would not be difficult to create anywhere in the world conditions similar to those in Reichenstein and Córdoba, simply by the long-continued use of arsenical insecticides in the United States, the arsenic-drenched soils of tobacco plantations, of many orchards in the Northwest, and of blueberry lands in the East may easily lead to the pollution of water supplies.

Some of the many new chemicals we are exposed to are also proving to be carcinogenic—by no means only pesticides, to be sure, though pesticides are prominent among them. In laboratory tests on animal subjects, DDT has produced suspicious liver tumors. Scientists of the Food and Drug Administration, who reported the discovery of these tumors, were uncertain how to classify them but felt that there was some "justification for considering them low grade hepatic cell carcinomas." Dr. Hueper now definitely rates DDT as a "chemical carcinogen." The weed killer aminotriazole has been proved to cause thyroid cancer in test animals. In 1959, this chemical was misused by a number of cranberry growers in such a way as to produce residues on some of the marketed berries. The Food and Drug Administration seized the contaminated cranberries, and in the controversy that inevitably followed, the contention that the chemical actually was cancer-producing was challenged, even by many medical men. The scientific facts released by the Food and Drug Administration, however, clearly show aminotriazole to be carcinogenic in laboratory rats. When these animals had been given the chemical at the rate of a hundred parts per million in their drinking water—that is, one teaspoonful of chemical in ten thousand teaspoonfuls of water for sixty-eight weeks, they began to develop thyroid tumors. After two years, such tumors were present in more than half the rats examined. They were diagnosed as benign and malignant growths of various types. The tumors also appeared when the concentration of the chemical was reduced; in fact, a concentration that produced no effect was not found. No one knows, of course, the concentration of which aminotriazole may be carcinogenic for man, but, as a professor of medicine at Harvard, Dr. David Rutstein, has pointed out, this concentration is just as likely to be lower than that for rats as it is to be higher.

Insufficient time has elapsed since the introduction of the chlorinated-hydrocarbon insecticides and the modern herbicides to reveal their full effects. Most malignancies develop slowly. In the early nineteen-twenties, women who painted luminous figures on watch dials swallowed minute amounts of radium as a result of touching the brushes to their lips, and in some of these women bone cancers developed after a lapse of more than fifteen years. A period of thirty years, or even more, has been demonstrated for some cancers caused by occupational exposures to carcinogens. The first exposures to the new synthetic pesticides date from about 1942 for military personnel and from about 1945 for civilians, and it was not until the early fifties that a wide variety of pesticidal chemicals came into use, so the full maturing of whatever seeds of malignancy these chemicals have sown is yet to come. There is, however, one disease usually considered malignant that need have no long period of latency. This is leukemia in its acute form. Survivors of Hiroshima began to develop leukemia only three years after the atomic bombing, and there is now reason to believe that the latent period may sometimes be considerably shorter. Within the period covered by the rise of modern chemicals, the incidence of leukemia, too, has been steadily rising. Figures available from the Office of Vital Statistics clearly establish this fact. In the year 1960, leukemia alone claimed 12,290 victims, as opposed to 8,845 in 1950. Deaths from all types of malignancies of the blood and lymph totalled 25,400, as opposed to 16,690 in 1950. In terms of deaths per hundred thousand of population, the figure for 1950 was 11.1 and that for 1960 was 14.1. And in all countries the recorded deaths from leukemia, at an ages, are rising at a rate of between four and five per cent a year.

Such world-famous institutions as the Mayo Clinic now admit hundreds of victims of blood and lymph diseases. In case after case, a fateful sequence of events is revealed in the patient's recent history. Certain truths have become inescapably clear to Dr. Malcolm Hargraves, of the Hematology Department of the Mayo Clinic: in many cases, victims of leukemia, of a severe depression of the bone marrow called aplastic anemia, of Hodgkin's disease, and of other disorders of the blood and blood-forming tissues have had a history of exposure to modern chemicals—among them paints, fuel oils, and various sprays containing DDT, chlordane, BHC, the nitrophenols, the common moth crystal paradichlorobenzene, lindane, and, of course, the liquids in which they were dissolved or suspended. According to Dr. Hargraves, environmental diseases related to the use of various toxic substances have been increasing, particularly during the past ten years. "I believe that the vast majority of patients suffering from the blood dyscrasias and lymphoid diseases have a significant history of exposure to the various hydrocarbons, which in turn include most of the pesticides of today," he has said. "A careful medical history will almost invariably establish such a relationship."

What sort of exposure do the case histories show? Among those kept by Dr. Hargraves, exposure to a single chemical is the exception, rather than the rule. A commercial pesticide usually contains a combination of several chemicals suspended in a petroleum distillate, plus some dispersing agent. From the practical, rather than the medical, standpoint, however, this distinction is of little importance, because these petroleum distillates are an inseparable part of most common sprays. A typical case history concerns a housewife who abhorred spiders. In mid-August, she went into her basement with an aerosol spray containing DDT and petroleum distillate. She sprayed the entire basement thoroughly—under the stairs, in the fruit cupboards, and around the ceiling and the rafters. As she finished the spraying, she became quite ill, experiencing nausea and extreme anxiety and nervousness. Within the next few days, however, she felt better, and, apparently not suspecting the cause of her difficulty, she repeated the entire procedure twice in September. After the third use of the aerosol, new symptoms developed—fever, general malaise, pains in the joints, and acute phlebitis in one leg. When she was examined by Dr. Hargraves, in October, she was found to be suffering from acute leukemia. She died within a month. Another of Dr. Hargraves' patients sprayed the basement and all the secluded areas of a roach-infested building with a twenty-five-per-cent concentration of DDT in a solvent containing methylated naphthalenes. Within a short time, he began to bruise and bleed. He entered the Clinic with a number of hemorrhages. Studies of his blood revealed aplastic anemia. During the next five and a half months, he received fifty-nine transfusions, in addition to other therapy. There was partial recovery, but about nine years later a fatal leukemia developed.

The medical literature of this country and others contains many cases that support the belief in a cause-and-effect relation between the new chemicals and leukemia and other blood disorders. The cases involve farmers caught in the "fallout" of their own spray rigs or of planes, a college student who sprayed his room for ants and remained in the room to study, a woman who had installed a portable lindane vaporizer in her home, and a worker in a cotton field that had been sprayed with chlordane and toxaphene. And then there was a Swedish farmer whose case is strangely reminiscent of that of the Japanese fisherman Aikichi Kuboyama, of the tuna vessel the Lucky Dragon. Like Kuboyama, the farmer had been a healthy man, gleaning his living from the land as Kuboyama gleaned his from the sea. For each man, a poison drifting in the sky carried a death sentence. For one, it was radioactive ash. For the other, it was chemical dust. One day early in May, the farmer treated about sixty acres of land with a dust containing DDT and BHC. As he worked, puffs of wind brought little clouds of the dust swirling about him. "In the evening he felt unusually tired, and during the subsequent days he had a general feeling of weakness, with backache and aching legs as well as chills, and was obliged to take to his bed," says a report from the medical clinic at Lund. His condition became worse, and a week after the spraying he applied for admission to the local hospital. He had a high fever, and his blood count was abnormal. After two and a half months, he died. A post-mortem examination revealed a complete wasting away of the bone marrow.

The road to cancer may be an indirect one. A substance that is not a carcinogen in the ordinary sense may disturb the normal functioning of some part of the body in such a way that malignancy results. Important examples are the cancers, especially of the reproductive system, that appear to be linked with disturbances in the balance of the sex hormones, for these disturbances, in turn, may in certain cases be the result of something that affects the ability of the liver to preserve a proper level of the hormones. The chlorinated hydrocarbons are precisely the kind of agent that can do this. Both the male and the female hormones are, of course, normally present in the body, though in different proportions in the two sexes, and they perform a necessary growth-stimulating function in relation to the various organs of reproduction. In addition, we absorb synthetic hormones from external sources—cosmetics, drugs, and foods, among others. It is important that the body be protected against an imbalance of male and female hormones and against an excessive accumulation of either, and normally the liver provides this protection. It may not be able to inactivate the female hormones, or estrogens, however (although it continues to control the male hormones), if it has been damaged by disease or by chemicals, or if its supply of the B-complex vitamins is deficient. Under these conditions, the estrogens build up to abnormally high levels.

What are the effects? In animals, at least, there is abundant evidence from experiments. For example, an investigator at the Rockefeller Institute found that female rabbits whose livers had been damaged by disease showed a very high incidence of uterine tumors; these are thought to have developed because the liver was no longer able to inactivate the estrogens in the blood, with the result that they rose to a carcinogenic level. Extensive experiments on mice, rats, guinea pigs, and monkeys show that the prolonged administration of estrogens—not necessarily at high levels—has caused changes in the tissues of the reproductive organs, varying from benign overgrowths to definite malignancy. Tumors of the kidneys have been induced in hamsters by the administration of estrogens. Although medical opinion is divided on the question, much evidence exists to support the view that similar effects may occur in human tissues. Investigators at the Royal Victoria Hospital at McGill University who studied a hundred and fifty cases of uterine cancer found that two-thirds of these occurred in patients whose estrogen levels were abnormally high. Of a later series, of twenty cases, ninety per cent had similarly high estrogen levels.

Liver damage sufficient to interfere with the inactivation of estrogens can be caused by the chlorinated hydrocarbons, which set up changes in liver cells at very low levels of intake. Also, like any other substances that destroy oxidative enzymes, they can cause loss of the B vitamins, which, as certain other chains of evidence have shown, play a protective role against cancer. The late C. P. Rhoads, onetime director of the Sloan-Kettering Institute for Cancer Research, found that test animals exposed to a very potent chemical carcinogen developed no cancer if they had been fed yeast, a rich source of the natural B vitamins. In experiments carried out in the nineteen-forties, a deficiency of these vitamins was found to accompany mouth cancer and perhaps cancer of other parts of the digestive tract as well. This has been observed both in the United States and in the northern parts of Sweden and Finland, where the diet is ordinarily deficient in vitamins. Certain groups of people—the Bantu tribes of Africa, for example—are especially prone to primary liver cancer, and such groups typically suffer from malnutrition. Cancer of the male breast is also prevalent in parts of Africa, and is typically associated with liver disease and malnutrition.

Here, again, in the field of cancer—whether brought about directly or indirectly—we see a familiar pattern. Human exposures to dangerous chemicals, including pesticides, are uncontrolled, and they are multiple. An individual may have many different exposures to the same chemical. It is quite possible that while no one of these exposures would be sufficient to precipitate malignancy, any single supposedly "safe dose" might be enough to tip the scales already loaded with other "safe doses." And, again, the harm may be done by two or more carcinogens acting together. The individual exposed to DDT is almost certain to be exposed to other hydrocarbons—in, for instance, solvents, paint removers, degreasing agents, dry-cleaning fluids, and anesthetics. What, then, can be a "safe dose" of DDT? The situation is made still more complicated by the fact that one chemical may act on another to alter its effect. Cancer may sometimes result from the complementary action of two chemicals, one of which sensitizes the cell or tissue so that later, under the action of a second, so-called promoting agent, it develops malignancy; for example, the herbicides IPC and CIPC, members of the carbamate group, may act as initiators in the production of skin tumors, sowing the seeds of malignancy, which may be brought into actual being by other substances. Such interaction may be complex and far-reaching. Water-pollution experts throughout the United States are concerned over the fact that detergents are now a troublesome and practically universal contaminant of public water supplies, and that there is no practical way to remove them by treatment. Some detergents may promote cancer in an indirect way—acting on the lining of the digestive tract and changing its tissues so that they more easily absorb dangerous chemicals, whose effect is thereby aggravated. Who can foresee and control this action? In the kaleidoscope of shifting conditions, what dose of even an indirect cancer-promoting agent can be "safe" except a zero dose? As it happens, this question has been a center of controversial discussion and some action. In 1958, the Food Additives Amendment of the Federal Food, Drug, and Cosmetic Act, which applies to substances actually incorporated into food, and not to pesticides, placed carcinogens in a different category from other toxic substances. What this meant was that whereas the Food and Drug Administration was granted administrative discretion in establishing safe levels of food additives in general, any substance found to induce cancer in man or animals was automatically branded unsafe and its use as a food additive prohibited. And in a celebrated instance, in 1959, Arthur S. Flemming, Secretary of Health, Education and Welfare, applied "zero tolerance" to a pesticide when he prohibited the sale in interstate commerce of cranberries bearing residues of the carcinogenic weed killer aminotriazole.

We tolerate cancer-causing agents in our environment at our peril, as a recent event clearly illustrates. In the spring of 1961, an epidemic of liver cancer appeared among rainbow trout in man federal, state, and private hatcheries. Trout in both the Eastern and the Western parts of the United States were affected, and in some areas practically a hundred per cent of the trout over three years of age developed cancer. This discovery was made by virtue of a preëxisting arrangement between the Fish and Wildlife Service and the environmental-cancer section of the National Cancer Institute, whereby the former would report the existence of tumors in any fish to the latter, as a precaution against a cancer hazard to man from water contaminants. Studies are still under way to determine the exact cause of this epidemic over so wide an area, but the best evidence is said to point to some substance present in the prepared hatchery feeds, which contain an incredible variety of chemical additives and medicinal agents. The story of the trout is important for many reasons, but chiefly as an example of what can happen when a potent carcinogen is introduced into the environment of any species. Dr. Hueper has interpreted this epidemic as a serious warning that greatly increased attention must be given to controlling the number and variety of environmental carcinogens. "If such preventive measures are not taken," he says, "the stage will be set at a progressive rate for the future occurrence of a similar disaster to the human population."

The discovery that we are living in what another investigator has called "a sea of carcinogens" is, of course, dismaying, and may easily lead to a reaction of despair and defeatism. "Isn't it a hopeless situation?" is the common response. "Isn't it impossible even to attempt to eliminate these cancer-producing agents from our world? Wouldn't it be better not to waste time trying, and to devote all our efforts to research to find a cure for cancer instead?" When this question is put to Dr. Hueper, he replies with the thoughtfulness of one who has pondered it long. He believes that our situation today with regard to cancer is very similar to that which faced mankind with regard to infectious diseases in the latter part of the nineteenth century. Thanks to the brilliant work of Pasteur and Koch, medical men, and even the general public, were becoming aware that the human environment was inhabited by an enormous number of microorganisms capable of causing disease, just as today we are increasingly conscious of the carcinogens that pervade our surroundings. Defeatism was clearly not the answer in the case of infectious diseases, for, as we have seen, most of them have been brought under a reasonable degree of control, and some have been practically eliminated. This brilliant medical achievement came about by an attack that was twofold—one that stressed prevention as well as cure. Despite the prominence given to "magic bullets" and "wonder drugs," most of the really decisive battles in the war against infectious disease consisted of measures to eliminate disease organisms from the environment. An example from history concerns the great outbreak of cholera in London more than a hundred years ago. A London physician, John Snow, mapped the occurrence of cases and found that they originated in one area, all of whose inhabitants drew their water from a pump on Broad Street. In a swift and decisive stroke of preventive medicine, Dr. Snow removed the handle from the pump, and the epidemic was thereby brought under control. Even therapeutic measures have the result not only of curing the patient but of reducing the foci of infection; for example, the present comparative rarity of tuberculosis is to a considerable extent a result of the fact that nowadays the average person seldom comes in contact with the tubercle bacillus. Today we are surrounded by a great variety of cancer-producing agents. In Dr. Hueper's opinion, an attack on cancer that is concentrated wholly, or even largely, on therapeutic measures (even assuming that a "cure" can be found) will fail, because it will leave untouched the great reservoirs of carcinogens.

Why have we been slow to adopt this common-sense approach to the cancer problem? Probably because, as Dr. Hueper puts it, "the goal of curing the victims of cancer is more exciting, more tangible, more glamorous, and more rewarding than prevention." Yet the task of preventing cancer is by no means a hopeless one. In one important respect, indeed, the outlook is more encouraging than the situation in regard to infectious disease was at the turn of the century. Man had not put the germs into the environment, and his role in spreading them was involuntary. By contrast, man has put the vast majority of carcinogens into the environment, and he can, if he wishes, eliminate many of them. The chemical agents of cancer have—ironically—become entrenched in our world through man's search for a better and easer way of life. It would be unrealistic to suppose that all of them can or will be eliminated from the modern world, but of the agents responsible for the American Cancer Society's current prediction that one person in every four will develop cancer, a very large proportion are by no means necessities of life. By their elimination, the total load of carcinogens would be enormously lightened. In the interests of those in whom cancer is already a hidden or a visible presence, efforts to find cures must, of course, continue. But for those not yet touched by the disease, and certainly for the generations yet unborn, prevention is the imperative need.

Anyone who doubts that the age we live in is an age of poisons has only to walk into a grocery store, where he will find that, with no questions asked, he can buy substances of far greater death-dealing power than the medicinal drug for which he may be required to sign a "poison book" in the pharmacy next door. A few minutes' research in any supermarket would be enough to alarm the most stout-hearted customer if only he had ever been given a few basic facts about the chemicals presented for his choice. If a huge skull and crossbones were suspended above the insecticide department, the customer might at least enter it with the respect normally accorded death-dealing materials, but instead the display is homey and cheerful, and, with the pickles and olives across the aisle, and the bath and laundry soaps adjoining, the rows upon rows of insecticides look harmless enough. Within easy reach of a child's exploring hand are chemicals in glass containers; if either a child or a careless adult should drop one of these to the floor, everyone nearby would be splashed with the same sort of chemical that has sent spraymen using it into convulsions. A can of a mothproofing material containing DDD, a relative of DDT, carries in very fine print the warning that its contents are under pressure and that it may burst if it is exposed to heat or open flame. A common insecticide for household use, including assorted uses in the kitchen, contains chlordane, though the Food and Drug Administration's chief pharmacologist has declared the potential hazard of living in a house sprayed with chlordane to be "quite great." Other household preparations contain the even more toxic dieldrin.

Use of the poisons is made attractive and easy. Shelf paper, white or tinted to match our kitchen color scheme, may be impregnated with insecticides, not merely on one side but on both. Manufacturers offer us do-it-yourself booklets on how to kill bugs. With push-button ease, we may send a fog of dieldrin into the most inaccessible nooks and crannies of our closets, cabinets, and baseboards. If we are troubled by mosquitoes, chiggers, or other insect pests on our persons, we have a choice of innumerable lotions, creams, and sprays for application to our skin or our clothing. A celebrated New York store advertises a pocket-sized insecticide dispenser, which can be tucked into the purse or into a beach bag, golf bag, or fishing creel. We can polish our floors with a wax guaranteed to kill insects that walk over it. The Department of Agriculture, in a Home and Garden Bulletin, advises us to spray our winter clothing with an oil solution of DDT, dieldrin, chlordane, or any of several other moth killers. All these matters having been attended to, we may round out our day with insecticides by going to sleep under a mothproof blanket impregnated with dieldrin.

Gardening is firmly linked with the new poisons. Every hardware store, garden-supply shop, and supermarket has rows of insecticides designed to cope with any conceivable horticultural situation. Every newspaper's garden page and the majority of the gardening magazines take the use of these substances for granted. So extensively are even the organic-phosphate insecticides, such as parathion and malathion, applied to lawns and ornamental plantings that in 1960 the Florida State Board of Health found it necessary to restrict the use of pesticides in residential areas; a number of deaths from parathion had occurred in Florida before this regulation was adopted. In general, however, little is done to warn the gardener or homeowner that he is handling extremely dangerous materials. On the contrary, a constant stream of new gadgets continues to make it easier to use poisons on lawn and garden—and to increase the gardener's contact with them. Power mowers have been fitted with devices for the dissemination of pesticides—attachments that will dispense a cloud of vapor as the homeowner mows his lawn. So to the potentially dangerous fumes from gasoline are added the finely divided particles of whatever insecticide the unsuspecting suburbanite has chosen to distribute, raising the level of air pollution above his own grounds to something that few cities could equal. Even the once innocuous garden hose has been fitted out with dangerous devices. One may get a jar-type attachment for the hose, for example, by which such chemicals as chlordane and dieldrin can be applied to the lawn as one waters it. Such an attachment is not only a hazard to the person using the hose; it is also a public menace. In 1960, the New York *Times* issued a warning on its garden page to the effect that unless special protective equipment was installed, poisons might get into the water supply by back siphonage. As an example of what can happen to the gardener himself, we might look at the case of a physician—an enthusiastic spare-time gardener—who took to using DDT and then malathion on his shrubs and lawn, making regular weekly applications. Sometimes he applied the chemicals with a hand spray, sometimes with a hose attachment.

Whichever method he used, his skin and clothing often became soaked with spray. After about a year of this, he suddenly collapsed and was hospitalized. Examination of a biopsy specimen of fat showed an accumulation of twenty-three parts per million of DDT. He had suffered extensive nerve damage, which his physicians regarded as permanent. As time went on, he lost weight, was subject to extreme fatigue, and experienced a peculiar muscular weakness.

The mores of suburbia now dictate that crab grass must go, at whatever cost, and sacks containing chemicals designed to rid the lawn of such despised vegetation have become almost a status symbol. These weed-killing chemicals are sold under brand names that hold no suggestion of their identity or their nature. The descriptive literature that may be picked up in any hardware or garden-supply store seldom, if ever, reveals the true hazards involved in handling or applying the material it recommends. Instead, the typical illustration portrays a happy family scene—father and son smiling as they prepare to apply the chemical to the lawn, or small children tumbling over the grass with a dog.

Indeed, the public is hardly ever made aware of the true nature of most of the pesticides. Advertisements for lindane, to take one example, contain no suggestion that the chemical is dangerous. Neither do advertisements for vaporizers that dispense lindane fumes; in fact, we are told that they are safe. Yet the truth of the matter is that the American Medical Association considers electronic vaporizers employing lindane so dangerous that it recently conducted an extended campaign against them in its *Journal*. To learn that sacks of weed killers contain chlordane or dieldrin, one must read exceedingly fine type placed on the least conspicuous part of the sacks. On containers of insecticides, warnings are printed so inconspicuously that few people take the trouble to read them. An industrial firm recently undertook to find out just how few. Its survey indicated that out of a hundred people using insecticide aerosols and sprays scarcely fifteen are aware that there are any warnings at all on the containers.

The question of chemical residues on the food we eat is the subject of a hot debate. The existence of such residues either is played down by the manufacturers of chemicals as unimportant or is flatly denied. Simultaneously, there is a strong tendency to brand as fanatics or cultists all who are so perverse as to demand that their food be free of insect poisons. In all this cloud of controversy, what are the facts?

Common sense tells us that the bodies of persons who lived and died before the dawn of the DDT era—that is, before about 1942—contained no trace of DDT or any similar material. Samples of body fat collected from the general population between 1954 and 1956 contained an average of from 5.3 to 7.4 parts per million of DDT. There is some evidence that the average level has been steadily rising since, and that individuals who incur occupational or other special exposure to insecticides consistently store even more. It has been assumed that among the general population, with no known gross exposures to insecticides, much of the DDT stored in fat deposits has entered the body in food. In 1954, a scientific team from the Public Health Service that had sampled restaurant and institutional meals in order to test this assumption reported that every meal contained DDT. From this the investigators concluded, reasonably enough, that “few if any foods can be relied upon to be entirely free of DDT.” Actually, the quantities of DDT in such meals may be enormous. In a separate Public Health Service study, an analysis of prison meals disclosed such items as stewed dried fruit containing 69.6 parts per million and bread containing 100.9 parts per million. In the diet of the average home, meats and the various products derived from fats contain the heaviest residues of chlorinated hydrocarbons, for the simple reason that these chemicals are soluble in fat. Residues on fruits and vegetables tend to be somewhat less. These are little affected by washing, however; the only remedy is to remove and discard all the outside leaves of such vegetables as lettuce and cabbage, to peel fruit, and to use no skins or other outer coverings whatever. Cooking does not destroy residues.

To find a diet free from DDT and related chemicals, it seems, one must go to a remote and primitive land. Such a land, or stretch of land, appears to exist on the far arctic shores of Alaska, although even there one may see the approaching shadow. A year or two ago, scientists investigated the native diet of the Eskimos of this region, and found it to be free from insecticides. The fresh and dried fish; the fat, oil, or meat from beaver, caribou, moose, polar bear, seal, and walrus; cranberries, salmonberries, and wild rhubarb—all had so far escaped contamination. When some of the Eskimos themselves were checked by analysis of fat samples, however, small residues of DDT were found (up to 1.9 parts per million). The reason for this was clear. The fat samples were taken from people who had left their native villages to enter the United States Public Health Service Hospital in Anchorage, for surgery. There the ways of civilization prevailed, and the meals in the hospital were found to contain as much DDT as those in the most populous city. For their brief stay in civilization, the Eskimos were rewarded with a taint of poison.

The fact that every meal we eat carries its load of chlorinated hydrocarbons is the inevitable consequence of the almost universal spraying or dusting of agricultural crops with these poisons. If the farmer scrupulously follows the instructions on the labels, his use of agricultural chemicals will produce no residues larger than those permitted by the Food and Drug Administration. To leave aside for the moment the question of whether these legal residues are as "safe" as they are represented to be, there remains the well-known fact that farmers very frequently exceed the prescribed dosages, use the chemical too close to the time of harvest, use several insecticides where one would do, and in other ways share the common human failing of neglecting to read the fine print. Even the chemical industry recognizes the frequent misuse of insecticides and the need for educating farmers in their application; one of its leading trade journals recently declared that "many users do not seem to understand that they may exceed insecticide tolerances if they use higher dosages than recommended—the haphazard use of insecticides on many crops may be based on farmers' whims." The files of the Food and Drug Administration contain records of a disturbing number of such haphazard uses. A few examples will serve to illustrate the disregard of directions: a lettuce farmer who applied not one but eight different insecticides to his crop within a short time of harvest, a shipper who used parathion on celery in an amount that was five times the recommended maximum, and growers who sprayed spinach with DDT a week before harvest. There are also cases of chance or accidental contamination. Large lots of green coffee in burlap bags have become contaminated while they were being transported in vessels that also carried a cargo of insecticides. Packaged foods in warehouses are subjected to repeated aerosol treatments with DDT, lindane, and other insecticides, which may penetrate the packaging materials and occur in measurable quantities on the foods. The longer the food remains in storage, the greater the danger of contamination.

To the question "But doesn't the government protect us from such things?" the answer is "Only to a limited extent." The Food and Drug Administration establishes maximum permissible limits of contamination, called "tolerances," which vary from food to food and from pesticide to pesticide. But the activities of the Food and Drug Administration in the field of consumer protection against pesticides are severely limited by two factors. The first is that it has jurisdiction only over foods shipped in interstate commerce; foods marketed within the state where they were grown are entirely outside its sphere of authority, no matter what the violation. Most states, it is important to note, have woefully inadequate laws in this field. The second, and even more critically limiting, factor is the small number of inspectors on the staff of the Food and Drug Administration—fewer than six hundred men for all its varied work. With the existing facilities, according to a Food and Drug official, only an infinitesimal fraction of the crop products moving in interstate commerce can be checked—far less than one per cent, or not enough to have statistical significance. Milk is one of the few foods in which no pesticide residues whatever are permitted by Food and Drug Administration regulations. In actuality, however, residues frequently turn up. They are heaviest in butter and other manufactured dairy products A check of four hundred and sixty-one samples of such products in 1960 showed that a third contained residues. One can imagine, then, the volume of contaminated and unchecked dairy products that we consume.

Beyond these limiting factors, the system under which the Food and Drug Administration establishes tolerances has obvious defects. Under the conditions prevailing, it provides mere paper security, and, in addition, it promotes a completely unjustified impression that safe limits have been established and are being adhered to. As for the safety of allowing a sprinkling of poisons on our food—a little on this, a little on that—many people argue that no poison is safe on food. In setting a tolerance level, the Food and Drug Administration reviews tests of the poison on laboratory animals and then establishes as the maximum level of contamination a quantity that is much less than that required to produce symptoms in the test animals. This system, which is supposed to insure safety, ignores a number of important facts. As we have noted, a laboratory animal, living under highly artificial conditions and consuming a given amount of a specific chemical, is very different from a human being, whose exposures to pesticides are not only multiple but for the most part unknown, unmeasurable, and uncontrollable. Even if seven parts per million of DDT on the lettuce in his luncheon salad were "safe," as the Food and Drug Administration declares, the meal includes several other foods with allowable residues of their own, and, of course, the pesticides on his food are only a part, and possibly a small part, of his total exposure. This piling up of chemicals from many different sources creates a total exposure that cannot he measured. It is meaningless, therefore, to talk about the "safety" of any specific amount of residue.

And there are other defects. Sometimes tolerances have been established on the basis of inadequate knowledge of the chemical concerned. In such cases, better information, or a review of existing information, has led to a later reduction or withdrawal of the tolerance, but only after the public has been exposed to admittedly dangerous levels of the chemical for months or years. This happened when heptachlor was given a tolerance, which later had to be revoked. In certain circumstances, a tolerance can be set up against the better judgment of Food and Drug Administration scientists, for the chemical manufacturer has the right to appeal to higher authority—in practice, a committee appointed by the

National Academy of Sciences. In one such case, the Food and Drug Administration found that a pesticide was carcinogenic, but, what with various administrative procedures, it was two years before this chemical could effectively be given a zero tolerance. And, to compound the Food and Drug Administration's difficulties, no practical field method of analysis exists for some chemicals before they are registered for use, and inspectors are frustrated in their efforts to detect residues.

What is the solution to the problem of contaminated food? The first necessity is to eliminate tolerances for the chlorinated hydrocarbons, the organic-phosphate group, and the rest of the highly toxic chemicals. It may be objected that this will place too much of a burden on the farmer. But if, as is now presumed to be true, it is possible to use chemicals in such a way that they leave a residue of only one part per million (the tolerance for DDT on potatoes), or even of only 0.1 part per million (the tolerance for dieldrin on a great variety of fruits and vegetables), then why is it not possible, with only a little more care, to prevent the occurrence of any residues at all? The fact is that a zero tolerance is already required for certain chemicals on certain crops. If it is considered practical in these instances, why not in all? Yet even a zero tolerance is not a complete solution, with more than ninety-nine per cent of our interstate food shipments slipping by without inspection. A vigilant and aggressive Food and Drug Administration, with a greatly increased force of inspectors, is another urgent need. And still another need is strict inspection and control of foods that never leave the state where they are produced.

This system, however—poisoning our food and then policing the result—is too reminiscent of Lewis Carroll's White Knight, who thought of "a plan to dye one's whiskers green, and always use so large a fan that they could not be seen." The ultimate answer is to use chemicals that are less toxic, so that the public hazard from any misuse will be much reduced. Such chemicals already exist: the pyrethrins, which are made from the dried flowers of chrysanthemums; rotenone, which occurs in the roots of an East Indian plant; ryania, which is found in the stem wood of a shrub native to South America; and others, also derived from plant substances. (For some time, a critical shortage of the pyrethrins appeared imminent, but these substances have recently been duplicated synthetically, so they should now be readily available.) In addition to making this change in the nature of chemical pesticides, we should diligently explore the possibilities of non-chemical methods of pest control. The use of insect diseases—caused by bacteria and viruses that attack certain types of destructive insects—has already been successful in some areas, and more extended tests of this method are planned. A great many other possibilities also exist for effective insect control by methods that will leave no residues on foods. But until a large-scale conversion to these methods has occurred, we shall have little relief from a situation that, by any common-sense standards, is intolerable. As things are now, we are little better off than guests of the Borgias.

The problem that this series of articles has attempted to make clear is that our world has been widely contaminated with the substances used in the control of insects—chemicals that have already invaded the water on which all living things depend, have entered into the soil, and have spread a toxic film over vegetation. The new chemicals do not single out the one species of which we desire to be rid. Each of them is used for the simple reason that it is a deadly poison. It therefore poisons all life with which it comes in contact—the cat beloved of a family, the farmer's cattle, the rabbit in the field, and the horned lark in the sky. These creatures are innocent of any harm to man. Indeed, by their very existence they make his life more pleasant. Yet he rewards them with a death that is sudden and horrible. The bird life of whole regions has already been almost wiped out, the fish of rivers and lakes have been destroyed, and lingering poisons have become lodged in the bodies of creatures ranging from the earthworms of the soil to the wild game of the forest. As for man himself, there is no reason to believe he is immune to the poisons that have already brought death to so many of these creatures with which he shares the earth. Where the effects on man are already known, they are found to be destructive. Beyond these known effects is the even more frightening prospect of damage that cannot be detected for years and of possible genetic effects that cannot be known for generations, by which time the havoc we have wrought cannot be undone. And it is ironic that in inflicting so much damage and incurring such risks we have destroyed many of the defenses in nature that are our true protection against the excessive multiplication of any species of insect, while even as we have done so, the insects that most seriously threaten our welfare have developed resistance to the chemicals used against them, raising the threat that we may lose control over insect-borne disease.

My contention is not that moderate chemical controls should never be used under any circumstances but, rather, that we must reduce their use to a minimum and must as rapidly as possible develop and strengthen biological controls. I contend that we have put poisonous and biologically potent chemicals indiscriminately into the hands of persons who are largely or wholly ignorant of the harm they can do. There is still a very limited awareness of the nature of the threat. This is an era of specialists, each of whom sees his own problem and is unaware of or indifferent to the larger frame into which it fits. It is also an era dominated by industry, in which the right to make money, at whatever cost to others, is seldom challenged. We shall have no relief from this poisoning of the environment until our officials have the courage and integrity to declare that the public welfare is more important than dollars, and to enforce this point of view in the face of all pressures and all protests, even from the public itself. On those occasions when the public, confronted with some obvious evidence of the damaging results of pesticide applications, has ventured to question the use of poisonous chemicals, it has been fed little tranquillizing pills of half truth. We urgently need to put an end to these false assurances. It is the public that is being asked to assume the risks that the insect controllers calculate. The public must decide whether it wishes to continue on the present road, and it can do so only when it is in full possession of the facts. In the words of the French biologist Jean Rostand, "The obligation to endure gives us the right to know." ♦

_(This is the last of a series of articles.)

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