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About the Author

Rachel Carson (1907–64) wanted to be a writer for as long as she could remember. However, while at Pennsylvania College for Women (now Chatham College), she changed her major from literature to biology, graduating in 1929 at a time when there were few women in science. She completed an MA in marine zoology at Johns Hopkins University, taught at the University of Maryland, and published articles on natural history in the Baltimore Sun. From 1937 to 1952 she was an aquatic biologist for the U.S. Fish and Wildlife Service, resigning from her position of editor-in-chief to devote herself to writing.

Carson's unique combination of lyrical prose and accurate science earned her international literary acclaim with the publication of *The Sea Around Us* in 1951. She was awarded the National Book Award for Non-Fiction, the John Burroughs Medal, the Gold Medal of the New York Zoological Society and the Audubon Society Medal. Carson was a fellow of the Royal Society of Literature and was elected into the American Academy of Arts and Letters.

Her first book, *Under the Sea Wind*, appeared in 1941. *Silent Spring*, which alerted the world to the dangers of the misuse of pesticides, was published in 1962. Carson's articles on natural history appeared in the *Atlantic Monthly*, the *New Yorker, Reader's Digest* and *Holiday*. An ardent ecologist and preservationist, Carson warned against the dumping of atomic waste at sea and predicted global warming. *The Edge of the Sea*, which completed her biography of the sea, is also published in Penguin Twentieth-Century Classics. Rachel Carson died of cancer at the age of 56.

Linda Lear is Research Professor of Environmental History at George Washington University. She is the author of *Rachel Carson:*

Witness for Nature, published in Penguin, and the editor of *Lost Woods: The Discovered Writing of Rachel Carson* (Beacon, 1998). She is at work on a new biography of a British writer and naturalist, and lives in Bethesda, Maryland.

PEGUIN BOOKS

Silent Spring

‘The revolution in our attitude towards pollution and the extravagant use of chemicals to control pests in the countryside is largely due to just one individual – Rachel Carson ... She was something rare for those times – a scientist who was also a brilliant writer’ Lewis Wolpert, *Sunday Times*

‘One of the first social critiques of modern industrial behaviour ... her tone and sharpness were luminous’ John Vidal, *Guardian*

‘Her warnings against organophosphates seem as relevant as ever, in the wake of Gulf War Syndrome and sheep-dip poisoning ... she opened her readers’ eyes to poetry and grandeur in the natural world, which they never realised to have existed’ Clive Aslet, *Observer*

‘A book which changed the way people looked at the world’ Antony Rouse, *Spectator*

‘She was the originator of ecological concern’ Doris Lessing, *Sunday Telegraph*

TO ALBERT SCHWEITZER
who said

‘Man has lost the capacity to foresee and to forestall. He will end by destroying the earth.’

The sedge is wither'd from the lake, And no birds sing.

KEATS

I am pessimistic about the human race because it is too ingenious for its own good. Our approach to nature is to beat it into submission. We would stand a better chance of survival if we accommodated ourselves to this planet and viewed it appreciatively instead of sceptically and dictatorially.

E. B. WHITE

Acknowledgements

In a letter written in January 1958, Olga Owens Huckins told me of her own bitter experience of a small world made lifeless, and so brought my attention sharply back to a problem with which I had long been concerned. I then realized I must write this book.

During the years since then I have received help and encouragement from so many people that it is not possible to name them all here. Those who have freely shared with me the fruits of many years' experience and study represent a wide variety of government agencies in this and other countries, many universities and research institutions, and many professions. To all of them I express my deepest thanks for time and thought so generously given.

In addition my special gratitude goes to those who took time to read portions of the manuscript and to offer comment and criticism based on their own expert knowledge. Although the final responsibility for the accuracy and validity of the text is mine, I could not have completed the book without the generous help of these specialists: L. G. Bartholomew, M.D., of the Mayo Clinic, John J. Biesele of the University of Texas, A. W. A. Brown of the University of Western Ontario, Morton S. Biskind, M.D., of Westport, Connecticut, C. J. Briejèr of the Plant Protection Service in Holland, Clarence Cottam of the Rob and Bessie Welder Wildlife Foundation, George Crile, Jr, M.D., of the Cleveland Clinic, Frank Egler of Norfolk, Connecticut, Malcolm M. Hargraves, M.D., of the Mayo Clinic, W. C. Hueper, M.D., of the National Cancer Institute, C. J. Kerswill of the Fisheries Research Board of Canada, Olaus Murie of the Wilderness Society, A. D. Pickett of the Canada Department of Agriculture, Thomas G. Scott of the Illinois Natural History Survey, Clarence Tarzwell of the Taft Sanitary Engineering Center, and George J. Wallace of Michigan State University.

Every writer of a book based on many diverse facts owes much to the skill and helpfulness of librarians. I owe such a debt to many, but especially to Ida K. Johnston of the Department of the Interior Library and to Thelma Robinson of the Library of the National Institutes of Health.

As my editor, Paul Brooks has given steadfast encouragement over the years and has cheerfully accommodated his plans to postponements and delays. For this, and for his skilled editorial judgement, I am everlastingly grateful.

I have had capable and devoted assistance in the enormous task of library research from Dorothy Algire, Jeanne Davis, and Bette Haney Duff. And I could not possibly have completed the task, under circumstances sometimes difficult, except for the faithful help of my housekeeper, Ida Sprow.

Finally, I must acknowledge our vast indebtedness to a host of people, many of them unknown to me personally, who have nevertheless made the writing of this book seem worth while. These are the people who first spoke out against the reckless and irresponsible poisoning of the world that man shares with all other creatures, and who are even now fighting the thousands of small battles that in the end will bring victory for sanity and common sense in our accommodation to the world that surrounds us.

RACHEL CARSON

Author's Note

I have not wished to burden the text with footnotes but I realize that many of my readers will wish to pursue some of the subjects discussed. I have therefore included a list of my principal sources of information, arranged by chapter and page, in an appendix which will be found at the back of the book.

R.C.

Introduction

In this brilliant and controversial book, Miss Rachel Carson brings her training as a biologist and her skill as a writer to bear with great force on a significant and even sinister aspect of man's technological progress. This is the story of the use of toxic chemicals in the countryside and of the widespread destruction of wildlife in America (caused by pesticides, fungicides and herbicides). But *Silent Spring* is not merely about poisons; it is about ecology or the relation of plants and animals to their environment and to one another. Ecologists are more and more coming to recognize that for this purpose man is an animal and indeed the most important of all animals and that however artificial his dwelling, he cannot with impunity allow the natural environment of living things from which he has so recently emerged to be destroyed. Fundamentally, therefore, Miss Carson makes a well-reasoned and persuasive case for human beings to learn to appreciate the fact that they are part of the entire living world inhabiting this planet, and that they must understand its conditions of existence and so behave that these conditions are not violated.

We in Britain have not yet been exposed to the same intensity of attack as in America, but here too there is a grim side to the story. There have been, for example, the reports of a mysterious illness affecting foxes. The first substantial records of the 'fox death' were in November 1959 from near Oundle, in Northamptonshire, and soon reports were coming in from all over the country until it was estimated that 1,300 foxes had been found dead. There was much speculation as to the cause. It was suggested that death was due to a virus disease. The symptoms were striking. Foxes appeared dazed, partially blind, hypersensitive to noise, almost dying of thirst, and then death came. One odd symptom, as the Nature Conservancy reported, was that sick foxes appeared to lose their

fear of mankind and were even to be found in such unlikely localities as the yard belonging to the Master of the Heythrop Hunt. No simple tests could at the time reveal the answer, but on the basis of more searching methods recently developed, 'fox death' is now generally believed to have been caused by the chlorinated hydrocarbons and other poisons so freely used in the countryside.

It was, however, the heaps of dead birds which revealed the truth. For many years biologists had given warning of danger, and already in 1960 voices were raised in Parliament and elsewhere demanding restriction and even a ban on chemicals such as dieldrin, aldrin, and heptachlor. It was clear that control over their use was quite inadequate and appeals were made by official bodies for more care. Then came the spring of 1961, when tens of thousands of birds were found littering the countryside, dead or dying in agony. The story from one estate alone reveals the nature of the tragedy. In the spring of 1960 at Tumby in Lincolnshire heavy losses of birds were reported. In 1961 over 6,000 dead birds were counted. From the royal estate at Sandringham in Norfolk the list of dead birds included pheasants, red-legged partridges, partridges, woodpigeons and stock doves, greenfinches, chaffinches, blackbirds, song thrushes, skylarks, moorhens, bramblings, tree sparrows, house sparrows, jays, yellow-hammers, hedge sparrows, carrion crows, hooded crows, goldfinches, and sparrowhawks. Over 142 bodies were collected in 11½ hours of special survey counts, and hundreds more over a period of weeks. Amongst these birds were some, such as the bramblings, which are specially protected by law, yet all went down before the indiscriminate scythe of toxic chemicals.

Following this catastrophe, further pressure was brought to bear. The matter was urgently debated in Parliament. The Ministry of Agriculture, Fisheries and Food called meetings, the Nature Conservancy, backed by naturalist societies such as the Royal Society for the Protection of Birds, the British Trust for Ornithology and the Game Research Association, intervened and finally a voluntary agreement was made to refrain from using certain seed dressings, except when an attack of wheat bulb fly was seriously anticipated, and then only for autumn sowings. But there is evidence that the poisoning from sprays still goes on,

though undoubtedly the voluntary ban has led to a marked reduction in the number of bird deaths caused by toxic seed dressings. Sowing conditions were particularly favourable in 1961–2 which must have had an effect in reducing the casualty figures, yet many deaths were reported from widely separated places. Once again the death roll was heavy at Tumby, especially of pheasants where the fertility of the surviving birds was seriously affected. Nest desertions began earlier in the year and out of a sample of 740 pheasants' eggs, the number hatched was well below the normal and many of the chicks were small and soon died. With the improved methods of analysis, it was found that in many of the unhatched eggs, there were present mercury and BHC (benzene hexachloride), both widely used as agricultural chemicals.

The story of the peregrine is particularly significant. It is typical of the change in our countryside which is being wrought by toxic chemicals. The peregrine, with other predators, has an important role to play in the ecology of the countryside. If you look at a map of the distribution of the peregrine in 1962 you will see that it has largely disappeared from the south of England. In the north of England peregrines are still present in fair numbers but although some pairs laid eggs, more than half of these failed. The position is similar in southern Scotland. Only in the highlands and islands has there been a fairly normal nesting season. Investigation of an egg taken from an abandoned nest near Perth showed that here again was poison.

Other predators, such as owls, have also been found dead. A significant example was that of a tawny owl from Kensington found dead on 9 July 1962. The bird was analysed by the Royal Society for the Protection of Birds' chemist and it was found to contain mercury, benzene hexachloride, heptachlor, and dieldrin. The tawny owl may well have been contaminated from eating rodents or insects in the gardens of London. A song thrush was also found dead in central London in the summer of 1962 with similar compounds in it. The number of garden chemicals on sale based on chlorinated hydrocarbons which are labelled 'safe' is a new and worrying factor, especially when one realizes that some of these contain chemicals similar to those that have wrought such havoc in the fields. It is possible that even our gardens are becoming extremely dangerous places for wildlife.

In this country there have been no great government agencies spraying whole counties and States as in America against the fire ant, the spruce bud worm or the gipsy moth and in the process seriously damaging not only wildlife but even killing domestic animals. The nearest we came to it was in the 1950s when commercial interests tried to persuade British highway authorities to switch over to the widespread use of herbicide sprays on roadside verges and hedgerows. The horrible consequence of this is well described from American experience by Rachel Carson, but in this country the Nature Conservancy, backed by enraged naturalists, managed to insist on a standstill, except for experimental treatments. Both scientific tests and cost analysis showed that inflated claims and unsubstantiated requirements for mass chemicals would not stand up to examination and, therefore, the British wayfarer and taxpayer has been spared the outrages recorded in *Silent Spring*, although strictly limited spraying on main roads here is now permitted.

The human side is perhaps the most sinister part of this book and here I must leave it to Miss Carson to tell her own very thorough story. The fact is that chemical residues are to be found in the food we eat. We are told officially that there is no hazard but we are also told by Professor Boyland, of the Chester Beatty Institute, that there is no safe dose for a carcinogen and, if there was, we would not know what it was. We are eating these chemicals, possibly in small, possibly in large quantities, and certainly they are being stored in our livers and our fat. Whether or not the evidence contained in Miss Carson's fully documented story is accepted, the fact remains that until a thing can be shown to be positively safe, we ought to reckon that any contaminant should be avoided. No one would suggest spraying fields with radioactivity, yet we do not pause before using mutagenic chemicals, the effects of which have in certain respects been shown by Dr Alexander, also of the Chester Beatty Institute, to be the same. This is no simple matter, for there are already many chemicals added to our food and there are some contaminants that occur in nature which can be dangerous to human beings.

It would be unfair to suggest that there is complete indifference in official quarters in Britain. Bodies like the British Industrial Biological Research Association have been recently set up and are

actively concerned with this problem. There are high-powered Government and scientific committees and the Ministry of Agriculture, Fisheries and Food, however bland its public face, now exercises effective control to prevent the poisoning of agricultural workers and is doing a good deal more work in other parts of the field than it is generally given credit for. The same is true also of the chemical companies.

While we need to look at both sides of the coin, to remember such disasters as the Irish potato famine, yet there is a feeling of lack of urgency about the dangers, especially the hidden ones, in the use of certain poisons. The agricultural Establishment is so convinced of the great benefit in increased production through the use of these chemicals that when they come to balance the problem in utilitarian terms, they find it difficult to see the wider and longer-term consequences. It looks as if we will go on swallowing these chemicals whether we like it or not and their real effect may not be seen for another twenty or thirty years.

Nor is anything like enough research being done. This was clearly revealed in the report of the Sanders Committee. Are the gains to mankind such that we should continue to take a risk which admittedly many experts, but certainly not all, regard as negligible and, if so, are we prepared to ignore the destruction of wildlife and the cruelty? Here there is another danger and one that the ecologist is particularly aware of. Some years ago a serious plague attacked the cocoa crops in West Africa. It was found that the disease was caused by a virus found in a coccid protected by ants. The counter-attack was made on the ants, and the disease was reduced; but the natural balance was upset and later there was an outbreak of no less than four new insect plagues! Another chlorinated hydrocarbon, DDT, is already proving consistently less effective. There are no less than twenty-six kinds of malaria-carrying anopheles mosquito which are DDT-proof and the chemical weapons may prove to have broken in our hands.

The science of ecology teaches us that we have to understand the interaction of all living things in the environment in which we live. Fortunately in Great Britain there is an official agency, the Nature Conservancy, which exists to study the natural environment and to learn from research and experiment how to manage it and safeguard it so that there can be a harmonious

coexistence between man and nature. Many people, however, look on the Conservancy as simply a body concerned with protecting birds, butterflies and wild flowers. It is urgently necessary that public opinion should understand more of the very serious and threatening problems with which such a body as the Conservancy has to deal, and *Silent Spring* will be an important means of enabling non-scientists to do so.

The soil is not an inert thing; it is full of minute living creatures and plants on which we depend. Yet we spray poison wholesale over it. The death of the predators is a warning to perhaps the greatest predator of all – mankind. Recently at the Wildlife Fund dinner in London, Prince Bernhard of the Netherlands said:

> We are dreaming of conquering space. We are already preparing the conquest of the moon. But if we are going to treat other planets as we are treating our own, we had better leave the Moon, Mars and Venus strictly alone!
>
> We are poisoning the air over our cities; we are poisoning the rivers and the seas; we are poisoning the soil itself. Some of this may be inevitable. But if we don't get together in a real and mighty effort to stop these attacks upon Mother Earth, wherever possible, we may find ourselves one day – one day soon, maybe – in a world that will be only a desert full of plastic, concrete and electronic robots. In that world there will be no more 'nature'; in that world man and a few domestic animals will be the only living creatures.
>
> And yet, man cannot live without some measure of contact with nature. It is essential to his happiness.

I would ask those who find parts of this book not to their taste or consider that they can refute some of the arguments to see the picture as a whole. We are dealing with dangerous things and it may be too late to wait for positive evidence of danger. The tragedies of Thalidomide, of lung cancer from smoking, and many other examples, all these are a measure of the failure to foresee the risk and act quickly enough. A distinguished British ecologist said to me that he thought *Silent Spring* overstated some things now but in ten years' time or less these could be understatements.

Ideally, we should seek more profound solutions – resistant crop strains which would be a slow business to develop and, above all, ecological management to promote a natural balance which will also suit the needs of man. At present the university training in these fields is slight. This is not a soft option for the scientist nor, therefore, for mankind but it is one which we must face. It means more funds for fundamental research and perhaps less for developing new things directly for the market. The wildlife tragedy in the countryside involves ethical and aesthetic values and may bear on man's very survival. As the Duke of Edinburgh said at the Wildlife Fund dinner:

> Miners use canaries to warn them of deadly gases. It might not be a bad idea if we took the same warning from the dead birds in our countryside.

SHACKLETON

House of Lords,
London

Preface

I am very glad to have a share in introducing Rachel Carson's important book to the British public, though there is little that I can add to Lord Shackleton's excellent Introduction.

However, I would like to mention a few points. Pest-control is of course necessary and desirable, but it is an ecological matter, and cannot be handed over entirely to the chemists. The present campaign for mass chemical control, besides being fostered by the profit motive, is another symptom of our exaggeratedly technological and quantitative approach. The ecological approach, on the other hand, involves aiming at a dynamic balance, an integrated pattern of adjustment between a number of competing factors or even apparently conflicting interests.

Ecology in the service of man cannot be merely quantitative or arithmetical: it has to deal with total situations and must think in terms of quality as well as of quantity. One conflict is between the present and the future, between immediate and partial interests and the continuing interests of the entire human species. Accordingly ecology must aim not only at optimum use but also at optimum conservation of resources. Furthermore, these resources include enjoyment resources like scenery and solitude, beauty and interest, as well as material resources like food or minerals; and against the interest of food-production we have to balance other interests, like human health, watershed protection, and recreation.

Some of the most striking results of mass use of chemical pesticides in Britain are the virtual disappearance of so many butterflies (the buddleias that used to attract swarms of Red Admirals and Peacocks now harbour only an occasional Lesser Tortoiseshell or Cabbage White; and the chalk downs are almost bare of Blues). Cuckoos have become quite scarce owing to caterpillars – their staple diet – being killed. Song-birds are

suffering from shortage of insect and worm food, as well as from the poisoning of what is left. Country hedgerows and road verges and meadows are losing their lovely and familiar flowers. In fact, as my brother Aldous said after reading Rachel Carson's book, we are losing half the subject-matter of English poetry.

The zeal for exterminating pests, rather than controlling them, of which Rachel Carson gives numerous examples, is another symptom of quantitative thinking. Indeed the very idea of extermination is unecological. It is almost certainly impossible to exterminate an abundant insect pest, but quite easy to exterminate non-abundant non-pests in the process.

It is not as if there were not methods of control available. Miss Carson gives a number of American examples of their success. One of the most interesting biological methods of controlling insect pests is by the release of irradiated males: these are sterile, and if present in sufficient numbers will enormously reduce the reproduction-rate.

Do not suppose that I am urging the abandonment of chemical control. We owe a great deal to the chemists who have given us methods of controlling the various pests that plague our lives. We have only to think of the value of antibiotics in controlling infectious disease, or of DDT in controlling malaria (though even here awkward and originally unforeseen consequences are cropping up in the shape of resistant strains of bacteria and mosquitoes). What I am against – and here I am sure that I speak for the great body of ecologists, naturalists, and conservationists – what I deplore is the advocacy and practice of mass chemical treatment as the main method of pest-control. On the contrary, though chemical control can be very useful, it too needs to be controlled, and should only be permitted when other methods are not available, and then under strict regulation and in relation to overall ecological planning.

In his closing paragraph Lord Shackleton refers to what is happening as a wildlife tragedy. It certainly is that; but it is also something more. It is an ecological tragedy. It is playing a big part in the process by which man is progressively ruining and destroying his own habitat. We must control the pest-controllers before the process gets out of hand.

JULIAN HUXLEY

CHAPTER I

A Fable for Tomorrow

There was once a town in the heart of America where all life seemed to live in harmony with its surroundings. The town lay in the midst of a checkerboard of prosperous farms, with fields of grain and hillsides of orchards where, in spring, white clouds of bloom drifted above the green fields. In autumn, oak and maple and birch set up a blaze of colour that flamed and flickered across a backdrop of pines. Then foxes barked in the hills and deer silently crossed the fields, half hidden in the mists of the autumn mornings.

Along the roads, laurel, viburnum and alder, great ferns and wildflowers delighted the traveller's eye through much of the year. Even in winter the roadsides were places of beauty, where countless birds came to feed on the berries and on the seed heads of the dried weeds rising above the snow. The countryside was, in fact, famous for the abundance and variety of its bird life, and when the flood of migrants was pouring through in spring and autumn people travelled from great distances to observe them. Others came to fish the streams, which flowed clear and cold out of the hills and contained shady pools where trout lay. So it had been from the days many years ago when the first settlers raised their houses, sank their wells, and built their barns.

Then a strange blight crept over the area and everything began to change. Some evil spell had settled on the community:

mysterious maladies swept the flocks of chickens; the cattle and sheep sickened and died. Everywhere was a shadow of death. The farmers spoke of much illness among their families. In the town the doctors had become more and more puzzled by new kinds of sickness appearing among their patients. There had been several sudden and unexplained deaths, not only among adults but even among children, who would be stricken suddenly while at play and die within a few hours.

There was a strange stillness. The birds, for example – where had they gone? Many people spoke of them, puzzled and disturbed. The feeding stations in the backyards were deserted. The few birds seen anywhere were moribund; they trembled violently and could not fly. It was a spring without voices. On the mornings that had once throbbed with the dawn chorus of robins, catbirds, doves, jays, wrens, and scores of other bird voices there was now no sound; only silence lay over the fields and woods and marsh.

On the farms the hens brooded, but no chicks hatched. The farmers complained that they were unable to raise any pigs – the litters were small and the young survived only a few days. The apple trees were coming into bloom but no bees droned among the blossoms, so there was no pollination and there would be no fruit.

The roadsides, once so attractive, were now lined with browned and withered vegetation as though swept by fire. These, too, were silent, deserted by all living things. Even the streams were now lifeless. Anglers no longer visited them, for all the fish had died.

In the gutters under the eaves and between the shingles of the roofs, a white granular powder still showed a few patches; some weeks before it had fallen like snow upon the roofs and the lawns, the fields and streams.

No witchcraft, no enemy action had silenced the rebirth of new life in this stricken world. The people had done it themselves.

This town does not actually exist, but it might easily have a thousand counterparts in America or elsewhere in the world. I know of no community that has experienced all the misfortunes I describe. Yet every one of these disasters has actually happened somewhere, and many real communities have already suffered a substantial number of them. A grim spectre has crept upon us

almost unnoticed, and this imagined tragedy may easily become a stark reality we all shall know.

What has already silenced the voices of spring in countless towns in America? This book is an attempt to explain.

– five hundred new chemicals to which the bodies of men and animals are required somehow to adapt each year, chemicals totally outside the limits of biologic experience.

Among them are many that are used in man's war against nature. Since the mid 1940s over two hundred basic chemicals have been created for use in killing insects, weeds, rodents, and other organisms described in the modern vernacular as 'pests'; and they are sold under several thousand different brand names.

These sprays, dusts and aerosols are now applied almost universally to farms, gardens forests, and homes – non-selective chemicals that have the power to kill every insect, the 'good' and the 'bad', to still the song of birds and the leaping of fish in the streams, to coat the leaves with a deadly film, and to linger on in soil – all this though the intended target may be only a few weeds or insects. Can anyone believe it is possible to lay down such a barrage of poisons on the surface of the earth without making it unfit for all life? They should not be called 'insecticides', but 'biocides'.

The whole process of spraying seems caught up in an endless spiral. Since DDT was released for civilian use, a process of escalation has been going on in which ever more toxic materials must be found. This has happened because insects, in a triumphant vindication of Darwin's principle of the survival of the fittest, have evolved super races immune to the particular insecticide used, hence a deadlier one has always to be developed – and then a deadlier one than that. It has happened also because, for reasons to be described later, destructive insects often undergo a 'flareback', or resurgence, after spraying, in numbers greater than before. Thus the chemical war is never won, and all life is caught in its violent crossfire.

Along with the possibility of the extinction of mankind by nuclear war, the central problem of our age has therefore become the contamination of man's total environment with such substances of incredible potential for harm – substances that accumulate in the tissues of plants and animals and even penetrate the germ cells to shatter or alter the very material of heredity upon which the shape of the future depends.

Some would-be architects of our future look towards a time when it will be possible to alter the human germ plasm by design.

But we may easily be doing so now by inadvertence, for many chemicals, like radiation, bring about gene mutations. It is ironic to think that man might determine his own future by something so seemingly trivial as the choice of an insect spray.

All this has been risked – for what? Future historians may well be amazed by our distorted sense of proportion. How could intelligent beings seek to control a few unwanted species by a method that contaminated the entire environment and brought the threat of disease and death even to their own kind? Yet this is precisely what we have done. We have done it, moreover, for reasons that collapse the moment we examine them. We are told that the enormous and expanding use of pesticides is necessary to maintain farm production. Yet is our real problem not one of *over-production*? Our farms, despite measures to remove acreages from production and to pay farmers *not* to produce, have yielded such a staggering excess of crops that the American taxpayer in 1962 is paying out more than one billion dollars a year as the total carrying cost of the surplus-food storage programme. And the situation is not helped when one branch of the Agriculture Department tries to reduce production while another states, as it did in 1958,

It is believed generally that reduction of crop acreages under provisions of the Soil Bank will stimulate interest in use of chemicals to obtain maximum production on the land retained in crops.

All this is not to say there is no insect problem and no need of control. I am saying, rather, that control must be geared to realities, not to mythical situations, and that the methods employed must be such that they do not destroy us along with the insects.

The problem whose attempted solution has brought such a train of disaster in its wake is an accompaniment of our modern way of life. Long before the age of man, insects inhabited the earth – a group of extraordinarily varied and adaptable beings. Over the course of time since man's advent, a small percentage of the more than half a million species of insects have come into conflict with

human welfare in two principal ways: as competitors for the food supply and as carriers of human disease.

Disease-carrying insects become important where human beings are crowded together, especially under conditions where sanitation is poor, as in time of natural disaster or war or in situations of extreme poverty and deprivation. Then control of some sort becomes necessary. It is a sobering fact, however, as we shall presently see, that the method of massive chemical control has had only limited success, and also threatens to worsen the very conditions it is intended to curb.

Under primitive agricultural conditions the farmer had few insect problems. These arose with the intensification of agriculture – the devotion of immense acreages to a single crop. Such a system set the stage for explosive increases in specific insect populations. Single-crop farming does not take advantage of the principles by which nature works; it is agriculture as an engineer might conceive it to be. Nature has introduced great variety into the landscape, but man has displayed a passion for simplifying it. Thus he undoes the built-in checks and balances by which nature holds the species within bounds. One important natural check is a limit on the amount of suitable habitat for each species. Obviously then, an insect that lives on wheat can build up its population to much higher levels on a farm devoted to wheat than on one in which wheat is intermingled with other crops to which the insect is not adapted.

The same thing happens in other situations. A generation or more ago, the towns of large areas of the United States lined their streets with the noble elm tree. Now the beauty they hopefully created is threatened with complete destruction as disease sweeps through the elms, carried by a beetle that would have only a limited chance to build up large populations and to spread from tree to tree if the elms were only occasional trees in a richly diversified planting.

Another factor in the modern insect problem is one that must be viewed against a background of geologic and human history: the spreading of thousands of different kinds of organisms from their native homes to invade new territories. This world-wide migration has been studied and graphically described by the British ecologist Charles Elton in his recent book *The Ecology of Invasions.* During the

Cretaceous Period, some hundred million years ago, flooding seas cut many land bridges between continents and living things found themselves confined in what Elton calls 'colossal separate nature reserves'. There, isolated from others of their kind, they developed many new species. When some of the land masses were joined again, about fifteen million years ago, these species began to move out into new territories – a movement that is not only still in progress but is now receiving considerable assistance from man.

The importation of plants is the primary agent in the modern spread of species, for animals have almost invariably gone along with the plants, quarantine being a comparatively recent and not completely effective innovation. The United States Office of Plant Introduction alone has introduced almost 200,000 species and varieties of plants from all over the world. Nearly half of the 180 or so major insect enemies of plants in the United States are accidental imports from abroad, and most of them have come as hitch-hikers on plants.

In new territory, out of reach of the restraining hand of the natural enemies that kept down its numbers in its native land, an invading plant or animal is able to become enormously abundant. Thus it is no accident that our most troublesome insects are introduced species.

These invasions, both the naturally occurring and those dependent on human assistance, are likely to continue indefinitely. Quarantine and massive chemical campaigns are only extremely expensive ways of buying time. We are faced, according to Dr Elton, 'with a life-and-death need not just to find new technological means of suppressing this plant or that animal'; instead we need the basic knowledge of animal populations and their relations to their surroundings that will 'promote an even balance and damp down the explosive power of outbreaks and new invasions'.

Much of the necessary knowledge is now available but we do not use it. We train ecologists in our universities and even employ them in our governmental agencies but we seldom take their advice. We allow the chemical death rain to fall as though there were no alternative, whereas in fact there are many, and our ingenuity could soon discover many more if given opportunity.

Have we fallen into a mesmerized state that makes us accept as inevitable that which is inferior or detrimental, as though having lost the will or the vision to demand that which is good? Such thinking, in the words of the ecologist Paul Shepard, idealizes life with only its head out of water, inches above the limits of toleration of the corruption of its own environment .... Why should we tolerate a diet of weak poisons, a home in insipid surroundings, a circle of acquaintances who are not quite our enemies, the noise of motors with just enough relief to prevent insanity? Who would want to live in a world which is just not quite fatal?

Yet such a world is pressed upon us. The crusade to create a chemically sterile, insect-free world seems to have engendered a fanatic zeal on the part of many specialists and most of the so-called control agencies. On every hand there is evidence that those engaged in spraying operations exercise a ruthless power. 'The regulatory entomologists ... function as prosecutor, judge and jury, tax assessor and collector and sheriff to enforce their own orders,' said Connecticut entomologist Neely Turner. The most flagrant abuses go unchecked in both state and federal agencies.

It is not my contention that chemical insecticides must never be used. I do contend that we have put poisonous and biologically potent chemicals indiscriminately into the hands of persons largely or wholly ignorant of their potentials for harm. We have subjected enormous numbers of people to contact with these poisons, without their consent and often without their knowledge. If the Bill of Rights contains no guarantee that a citizen shall be secure against lethal poisons distributed either by private individuals or by public officials, it is surely only because our forefathers, despite their considerable wisdom and foresight, could conceive of no such problem.

I contend, furthermore, that we have allowed these chemicals to be used with little or no advance investigation of their effect on soil, water, wildlife, and man himself. Future generations are unlikely to condone our lack of prudent concern for the integrity of the natural world that supports all life.

There is still 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 intolerant of the larger frame into which it

widely in association with the ores of various metals, and in very small amounts in volcanoes, in the sea, and in spring water. Its relations to man are varied and historic. Since many of its compounds are tasteless, it has been a favourite agent of homicide from long before the time of the Borgias to the present. Arsenic was the first recognized elementary carcinogen (or cancer-causing substance), identified in chimney soot and linked to cancer nearly two centuries ago by an English physician. Epidemics of chronic arsenical poisoning involving whole populations over long periods are on record. Arsenic-contaminated environments have also caused sickness and death among horses, cows, goats, pigs, deer, fishes, and bees; despite this record arsenical sprays and dusts are widely used. In the arsenic-sprayed cotton country of southern United States, beekeeping as an industry has nearly died out. Farmers using arsenic dusts over long periods have been afflicted with chronic arsenic poisoning; livestock have been poisoned by crop sprays or weed killers containing arsenic. Drifting arsenic dusts from blueberry lands have spread over neighbouring farms, contaminating streams, fatally poisoning bees and cows, and causing human illness.

> It is scarcely possible ... to handle arsenicals with more utter disregard of the general health than that which has been practised in our country in recent years [said Dr W. C. Hueper, of the National Cancer Institute, an authority on environmental cancer]. Anyone who has watched the dusters and sprayers of arsenical insecticides at work must have been impressed by the almost supreme carelessness with which the poisonous substances are dispensed.

Modern insecticides are still more deadly. The vast majority fall into one of two large groups of chemicals. One, represented by DDT, is known as the ‘chlorinated hydrocarbons’. The other group consists of the organic phosphorus insecticides, and is represented by the reasonably familiar malathion and parathion. All have one thing in common. As mentioned above, they are built on a basis of carbon atoms, which are also the indispensable building blocks of the living world, and thus classed as ‘organic’. To understand them, we must see of what they are made, and how, although

and winning the farmers' war against crop destroyers overnight. The discoverer, Paul Müller of Switzerland, won the Nobel Prize.

DDT is now so universally used that in most minds the product takes on the harmless aspect of the familiar. Perhaps the myth of the harmlessness of DDT rests on the fact that one of its first uses was the wartime dusting of many thousands of soldiers, refugees, and prisoners, to combat lice. It is widely believed that since so many people came into extremely intimate contact with DDT and suffered no immediate ill effects the chemical must certainly be innocent of harm. This understandable misconception arises from the fact that – unlike other chlorinated hydrocarbons – DDT *in powder form* is not readily absorbed through the skin. Dissolved in oil, as it usually is, DDT is definitely toxic. If swallowed, it is absorbed slowly through the digestive tract; it may also be absorbed through the lungs. Once it has entered the body it is stored largely in organs rich in fatty substances (because DDT itself is fat-soluble) such as the adrenals, testes, or thyroid. Relatively large amounts are deposited in the liver, kidneys, and the fat of the large, protective mesenteries that enfold the intestines.

This storage of DDT begins with the smallest conceivable intake of the chemical (which is present as residues on most foodstuffs) and continues until quite high levels are reached. The fatty storage depots act as biological magnifiers, so that an intake of as little as $\frac{1}{10}$ of 1 part per million in the diet results in storage of about 10 to 15 parts per million, an increase of one hundredfold or more. These terms of reference, so commonplace to the chemist or the pharmacologist, are unfamiliar to most of us. One part in a million sounds like a very small amount – and so it is. But such substances are so potent that a minute quantity can bring about vast changes in the body. In animal experiments, 3 parts per million has been found to inhibit an essential enzyme in heart muscle; only 5 parts per million has brought about necrosis or disintegration of liver cells; only 2.5 parts per million of the closely related chemicals dieldrin and chlordane did the same.

This is really not surprising. In the normal chemistry of the human body there is just such a disparity between cause and effect. For example, a quantity of iodine as small as two ten-thousandths of a gram spells the difference between health and disease. Because these small amounts of pesticides are

for the toxins may sleep long in his body, to become manifest months or years later in an obscure disorder almost impossible to trace to its origins. On the other hand, death may strike quickly. One victim who accidentally spilled a 25 per cent solution on his skin developed symptoms of poisoning within forty minutes and died before medical help could be obtained. No reliance can be placed on receiving advance warning which might allow treatment to be had in time.

Heptachlor, one of the constituents of chlordane, is marketed as a separate formulation. It has a particularly high capacity for storage in fat. If the diet contains as little as $\frac{1}{10}$ of 1 part per million there will be measurable amounts of heptachlor in the body. It also has the curious ability to undergo change into a chemically distinct substance known as heptachlor epoxide. It does this in soil and in the tissues of both plants and animals. Tests on birds indicate that the epoxide that results from this change is about four times as toxic as the original chemical, which in turn is four times as toxic as chlordane.

As long ago as the mid 1930s a special group of hydrocarbons, the chlorinated naphthalenes, was found to cause hepatitis, and also a rare and almost invariably fatal liver disease in persons subjected to occupational exposure. They have led to illness and death of workers in electrical industries; and more recently, in agriculture, they have been considered a cause of a mysterious and usually fatal disease of cattle. In view of these antecedents, it is not surprising that three of the insecticides that belong to this group are among the most violently poisonous of all the hydrocarbons. These are dieldrin, aldrin, and endrin.

Dieldrin, named after a German chemist, Diels, is about five times as toxic as DDT when swallowed but forty times as toxic when absorbed through the skin in solution. It is notorious for striking quickly and with terrible effect at the nervous system, sending the victims into convulsions. Persons thus poisoned recover so slowly as to indicate chronic effects. As with other chlorinated hydrocarbons, these long-term effects include severe damage to the liver. The long duration of its residues and the effective insecticidal action make dieldrin one of the most used insecticides today, despite the appalling destruction of wildlife

that has followed its use. As tested on quail and pheasants, it has proved to be about forty or fifty times as toxic as DDT.

There are vast gaps in our knowledge of how dieldrin is stored or distributed in the body, or excreted, for the chemists' ingenuity in devising insecticides has long ago outrun biological knowledge of the way these poisons affect the living organism. However, there is every indication of long storage in the human body, where deposits may lie dormant like a slumbering volcano, only to flare up in periods of physiological stress when the body draws upon its fat reserves. Much of what we do know has been learned through hard experience in the anti-malarial campaigns carried out by the World Health Organization. As soon as dieldrin was substituted for DDT in malaria-control work (because the malaria mosquitoes had become resistant to DDT), cases of poisoning among the spraymen began to occur. The seizures were severe – from half to all (varying in the different programmes) of the men affected went into convulsions and several died. Some had convulsions as long as *four months* after the last exposure.

Aldrin is a somewhat mysterious substance, for although it exists as a separate entity it bears the relation of alter ego to dieldrin. When carrots are taken from a bed treated with aldrin they are found to contain residues of dieldrin. This change occurs in living tissues and also in soil. Such alchemistic transformations have led to many erroneous reports, for if a chemist, knowing aldrin has been applied, tests for it he will be deceived into thinking all residues have been dissipated. The residues are there, but they are dieldrin and this requires a different test.

Like dieldrin, aldrin is extremely toxic. It produces degenerative changes in the liver and kidneys. A quantity the size of an aspirin tablet is enough to kill more than four hundred quail. Many cases of human poisonings are on record, most of them in connection with industrial handling.

Aldrin, like most of this group of insecticides, projects a menacing shadow into the future, the shadow of sterility. Pheasants fed quantities too small to kill them nevertheless laid few eggs, and the chicks that hatched soon died. The effect is not confined to birds. Rats exposed to aldrin had fewer pregnancies and their young were sickly and short-lived. Puppies born of treated mothers died within three days. By one means or another,

the new generations suffer for the poisoning of their parents. No one knows whether the same effect will be seen in human beings, yet this chemical has been sprayed from aeroplanes over suburban areas and farmlands.

Endrin is the most toxic of all the chlorinated hydrocarbons. Although chemically rather closely related to dieldrin, a little twist in its molecular structure makes it five times as poisonous. It makes the progenitor of all this group of insecticides, DDT, seem by comparison almost harmless. It is fifteen times as poisonous as DDT to mammals, thirty times as poisonous to fish, and about 300 times as poisonous to some birds.

In the decade of its use, endrin has killed enormous numbers of fish, has fatally poisoned cattle that have wandered into sprayed orchards, has poisoned wells, and has drawn a sharp warning from at least one state health department that its careless use is endangering human lives.

In one of the most tragic cases of endrin poisoning there was no apparent carelessness; efforts had been made to take precautions apparently considered adequate. A year-old child had been taken by his American parents to live in Venezuela. There were cockroaches in the house to which they moved, and after a few days a spray containing endrin was used. The baby and the small family dog were taken out of the house before the spraying was done about nine o'clock one morning. After the spraying the floors were washed. The baby and dog were returned to the house in mid-afternoon. An hour or so later the dog vomited, went into convulsions, and died. At 10 p.m. on the evening of the same day the baby also vomited, went into convulsions, and lost consciousness. After that fateful contact with endrin, this normal, healthy child became little more than a vegetable – unable to see or hear, subject to frequent muscular spasms, apparently completely cut off from contact with his surroundings. Several months of treatment in a New York hospital failed to change his condition or bring hope of change. 'It is extremely doubtful,' reported the attending physicians, 'that any useful degree of recovery will occur.'

The second major group of insecticides, the alkyl or organic phosphates, are among the most poisonous chemicals in the world.


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