

The New Yorker
[June 16, 1962 Issue](#)

Silent Spring—I

By [Rachel Carson](#)



Illustration by Emiliano Ponzi

I.

There was once a town in the heart of America where all life seemed to be 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 white clouds of bloom drifted above the green land. In autumn, oak and maple and birch set up a blaze of color that flamed and flickered across a backdrop of pines. Then foxes barked in the hills and deer crossed the fields, half hidden in the mists of the mornings. Along the roads, laurel, viburnum, and alder, great ferns and wild flowers 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 fall, people came from great distances to observe them. Other people came to fish 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, one spring, 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, and the cattle and sheep sickened and died. Everywhere was the shadow of death. The farmers told of

much illness among their families. In the town, the doctors were becoming more and more puzzled by new kinds of sickness that had appeared among their patients. There had been several sudden and unexplained deaths, not only among the adults but also among the children, who would be stricken while they were at play, and would die within a few hours. And there was a strange stillness. The birds, for example—where had they gone? Many people, baffled and disturbed, spoke of them. The feeding stations in the back yards were deserted. The few birds to be seen anywhere were moribund; they trembled violently and could not fly. It was a spring without voices. In the mornings, which had once throbbed with the dawn chorus of robins, catbirds, doves, jays, and wrens, and scores of other bird voices, there was now no sound; only silence lay over the fields and woods and marshes. 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 were lined with brown and withered vegetation, and were silent, too, deserted by all living things. Even the streams were 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 few patches of white granular powder could be seen; some weeks earlier this powder had been dropped, like snow, upon the roofs and the lawns, the fields and the streams. No witchcraft, no enemy action had snuffed out life in this stricken world. The people had done it themselves.

This town does not actually exist; I know of no community that has experienced all the misfortunes I describe. Yet every one of them has actually happened somewhere in the world, and many communities have already suffered a substantial number of them. A grim spectre has crept upon us almost unnoticed, and soon my imaginary town may have thousands of real counterparts. What is silencing the voices of spring in countless towns in America? I shall make an attempt to explain.

The history of life on earth is a history of the interaction of living things and their surroundings. To an overwhelming extent, the physical form and the habits of the earth's vegetation and its animal life have been molded and directed by the environment. Over the whole span of earthly time, the opposite effect, in which life modifies its surroundings, has been relatively slight. It is only within the moment of time represented by the twentieth century that one species—man—has acquired significant power to alter the nature of his world, and it is only within the past twenty-five years that this power has achieved such magnitude that it endangers the whole earth and its life. The most alarming of all man's assaults upon the environment is the contamination of the air, earth, rivers, and seas with dangerous, and even lethal, materials. This pollution has rapidly become almost universal, and it is for the most part irrecoverable; the chain of evil it initiates, not only in the world that must support life but in living tissues, is for the most part irreversible. It is widely known that radiation has done much to change the very nature of the world, the very nature of its life; strontium 90, released into the air through nuclear explosions, comes to earth in rain or drifts down as fallout, lodges in soil, enters into the grass or corn or wheat grown there, and, in time, takes up its abode in the bones of a human being, there to remain until his death. It is less well known that many man-made chemicals act in much the same way as radiation; they lie long in the soil, and enter into living organisms, passing from one to another.

Or they may travel mysteriously by underground streams, emerging to combine, through the alchemy of air and sunlight, into new forms, which kill vegetation, sicken cattle, and work unknown harm on those who drink from once pure wells. As Albert Schweitzer has said, "Man can hardly even recognize the devils of his own creation." It took hundreds of millions of years to produce the life that now inhabits the earth—aeons of time, in which that developing and evolving and diversifying life reached a state of adjustment to its surroundings. To be sure, the environment, rigorously shaping and directing the life it supported, contained hostile elements. Certain rocks gave out dangerous radiation; even within the light of the sun, from which all life draws its energy, there were short-wave radiations with power to injure. But given time—time not in years but in millennia—life adjusted, and a balance was reached. Time was the essential ingredient. Now, in the modern world, there is no time. The speed with which new hazards are created reflects the impetuous and heedless pace of man, rather than the deliberate pace of nature. Radiation is no longer merely the background radiation of rocks, the bombardment of cosmic rays, the ultraviolet of the sun, which existed before there was any life on earth; radiation is now also the unnatural creation of man's tampering with the atom. The chemicals to which life is asked to make its adjustment are no longer merely the calcium and silica and copper and the rest of the minerals washed out of the rocks and carried in rivers to the sea; they are also the synthetic creations of man's inventive mind, brewed in his laboratories and having no counterparts in nature. To adjust to these chemicals would require time on the scale that is nature's; it would require not merely the years of a man's life but the life of generations. And even this would be futile, for the new chemicals come in an endless stream; almost five hundred annually find their way into actual use in the United States alone. The figure is staggering and its implications are not easily grasped: five hundred new chemicals to which the bodies of men and all other living things are required somehow to adapt each year—chemicals totally outside the limits of biological experience.

Among the new chemicals are many that are used in man's war against nature. In the past decade and a half, some six hundred basic chemicals have been created for the purpose of killing insects, weeds, rodents, and other organisms described in the modern vernacular as "pests." In the form of sprays, dusts, and aerosols, these basic chemicals are offered for sale under several thousand different brand names—a highly bewildering array of poisons, confusing even to the chemist, which have the power to kill every insect, the "good" as well as the "bad," to still the song of birds and to stop the leaping of fish in the streams, to coat the leaves with poison and to linger on in soil. It may prove to be impossible to lay down such a barrage of dangerous poisons on the surface of the earth without making it unfit for all life. Indeed, the term "biocide" would be more appropriate than "insecticide"—all the more appropriate because the whole process of spraying poisons on the earth seems to have been caught up in an endless spiral. Since the late nineteen-forties, when DDT began to be used widely, a process of escalation has been going on in which ever more toxic chemicals must be found. This has happened because insects, in a triumphant vindication of Darwin's principle of the survival of the fittest, have consistently evolved super-races immune to the particular insecticide used, and hence a deadlier one has always had to be developed—and then a deadlier one than that. It has happened also that destructive insects often undergo a "flareback," or resurgence, after spraying, in numbers greater than before. The chemical war is never won, and all life is caught in its cross fire.

Along with the possibility of the extinction of mankind by nuclear war, a central problem of our age is the contamination of man's total environment with 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 toward a time when we will be able to alter the human germ plasm by design. But we may easily be altering it now by inadvertence, for many chemicals, like radiation, bring about gene mutations. It is ironic to think that man may determine his own future by something so seemingly trivial as the choice of his insect spray. The results, of course, will not be apparent for decades or centuries. 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 of weeds and insects by a method that brought the threat of disease and death even to their own kind?

The problem whose attempted solution has touched off such a train of disaster 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. Since man's advent, a small percentage of the more than half a million species of insects have come into conflict with human welfare, principally in two 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 when sanitation is poor, as in times of natural disaster or war, or in situations of extreme poverty and deprivation. As for insects that compete with man for food, they become important with the intensification of agriculture—the devotion of immense acreages to the production of a single crop. Such a system sets 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 various species within bounds. One important natural check is a limit on the amount of suitable habitat for each species. Obviously, an insect that lives on wheat can build up its population to much higher levels on a farm devoted solely to wheat than on a farm where wheat is intermingled with crops to which the insect is not adapted. In all such circumstances, insect control of some sort is necessary and proper. But in the case of both types of insect—the disease-carrying and the crop-consuming—it is a sobering fact that massive chemical control has had only limited success, and even threatens to worsen the very conditions it is intended to curb.

Another aspect of the insect problem is one that must be viewed against a background of geological and human history—the spreading of thousands of different kinds of organisms from their native homes into new territories. This worldwide migration has been studied and graphically described by the British ecologist Charles Elton in his recent book “The Ecology of Invasions by Animals and Plants.” During the Cretaceous period, some hundred million years ago, flooding seas created many islands within continents, and living things found themselves confined in what Elton calls “colossal separate nature reserves.” There, isolated from others of their kind, they developed large numbers of 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 not only is 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 never completely effective innovation. The United States government itself has imported approximately two hundred

thousand species or varieties of plants from all over the world. Nearly half of the hundred and eighty-odd major insect enemies of plants in the United States are accidental imports from abroad, and most of them have come as hitchhikers on plants. In new territory, out of reach of the natural enemies that kept down its numbers in its native land, an invading plant or animal is able to increase its numbers enormously. Realistically speaking, it would seem that insect invasions, both those occurring naturally and those dependent on human assistance, are likely to continue indefinitely. 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” but to acquire 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. Have we fallen into a mesmerized state that makes us accept as inevitable that which is inferior or detrimental, as though we had lost the will or the vision to demand that which is good? Such thinking, in the words of the American 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,” and he goes on to ask, “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 pollution of our environment has many sources—radioactive wastes, fallout from nuclear explosions, domestic wastes from cities and towns, and chemical wastes from factories as well as the new fallout from chemical sprays—and it affects every one of man’s natural resources. Of these, water has become the most precious. By far the greater part of the earth’s surface is covered by its seas, yet in the midst of this plenty we are in want. Most of the earth’s abundant water is not usable for agriculture, industry, or human consumption, because of its heavy load of salts, and so most of the world’s population either is experiencing critical shortages of water or is threatened with them. And the water that is usable has become—in an age when man has forgotten his origins and is blind to the very conditions that are most essential to his survival—the victim of man’s indifference.

Ever since chemists began to manufacture substances that nature never invented, the problems of water purification have grown more complex and the danger to users of water has increased. In rivers, a really incredible variety of pollutants is present, producing combined deposits that the sanitary engineers can only refer to despairingly as “gunk.” Professor Rolf Eliassen of the Massachusetts Institute of Technology testified before a congressional committee to the impossibility of identifying the organic matter resulting from the mixture. “We don’t know what that is,” said Professor Eliassen. “What is the effect on people? We don’t know.” We do know one thing, and that is that to an ever-increasing degree pesticides contribute to these organic pollutants. Because they become inextricably mixed with domestic and other wastes, they sometimes defy detection by the standard methods used in purification plants. Often they cannot be identified, and even if they are, most of them are so stable that they cannot be broken down by ordinary processes. Some are deliberately applied to bodies of water to destroy plants, insect larvae, or undesired fish. Some come from forest spraying, in the course of which two or three million acres of one of our states may be blanketed with spray directed against a single insect pest—spray that falls directly

into streams or else drips down through the leafy canopy to the forest floor, there to become part of the slow movement of seeping moisture beginning its long journey to the sea. Probably the bulk of such contaminants, however, consists of water-borne residues of the millions of pounds of agricultural chemicals that have been leached out of the ground by rains to become part of the same seaward movement.

Here and there we have dramatic evidence of the presence of these chemicals in our streams, and even in public water supplies. A sample of drinking water from an orchard area in Pennsylvania was tested on fish in a laboratory; it contained enough insecticide to kill all the fish within four hours. The runoff from fields treated with a chlorinated hydrocarbon called toxaphene killed all the fish in fifteen streams tributary to the Tennessee River, in Alabama, two of which were sources of municipal water supplies; the water remained poisonous for a week after the application of the insecticide—a fact that was determined by the daily deaths of goldfish suspended in cages downstream. For the most part, such pollution is invisible; it may make its presence known when hundreds or thousands of fish die, but more often it is never detected at all.

Anyone who doubts that our waters have become almost universally contaminated with insecticides might well study a brief report issued by the United States Fish and Wildlife Service in 1960. The Service had carried out studies to discover whether fish, like warm-blooded animals, store insecticides in their tissues. The first samples were taken from a creek in a forest area in the West where there had been mass spraying of DDT for the control of the spruce budworm. As might have been expected, all these fish contained DDT. The really significant findings were made when the investigators turned for comparison to a remote creek thirty miles from the nearest area sprayed for budworm control. This creek was upstream from the first, and separated from it by a high waterfall. No local spraying was known to have occurred. Yet the fish in that creek, too, contained DDT. Had the chemical been airborne, drifting down as fallout on the surface of the creek? Or had it reached the creek by hidden underground streams?

Probably no aspect of the entire water-pollution problem is more disturbing than the threat of widespread contamination of ground water. Seldom if ever does nature operate in separate compartments, and she has not done so in distributing the earth's water supply. As rain falls on the land, it seeps down through pores and cracks in soil and rock, penetrating deeper and deeper, until eventually it reaches a zone where all the pores of the bedrock are filled with water—a dark, subsurface sea, rising under hills, sinking beneath valleys. This ground water is always on the move, sometimes as slowly as fifty feet a year, sometimes as rapidly as nearly a tenth of a mile in a day. It travels unseen until, here and there, it comes to the surface as a spring, or perhaps is tapped to feed a well. But mostly it contributes invisibly to streams, and so to rivers. Except for the water that enters streams directly as rain or surface runoff, all the running water on the earth's surface was at one time ground water. And so pollution of the ground water is pollution of water everywhere.

It must have been by such a dark underground sea that poisonous chemicals travelled from a manufacturing plant in Colorado to a farming district several miles away. What happened, in brief, is this. In 1943 the Rocky Mountain Arsenal of the Army Chemical Corps, situated near Denver, began to manufacture war materials. Eight years later, the facilities of the arsenal were leased to a private oil company for the production of insecticides. Even before the changeover, however,

mysterious reports had begun to come in. Farmers several miles from the plant reported unexplained sickness among livestock, and they complained of extensive crop damage; foliage turned yellow, plants failed to mature, and many crops were killed outright. And there were reports of human illness. The waters used for the irrigation of these farms were derived from shallow wells. In 1959, a study was undertaken, in which several state and federal agencies participated, and when the well waters were examined they were found to contain an assortment of chemicals. Such wastes as chlorides, chlorates, salts of phosphonic acid, fluorides, and arsenic had been discharged from the Rocky Mountain Arsenal during the years of its operation by the Army Chemical Corps. It was concluded that some of these wastes had found their way into the ground water at the arsenal and that it had taken from seven to eight years for them to travel underground a distance of about three miles from two of the arsenal's original holding ponds—mere depressions in the earth, into which wastes were discharged—to the nearest farm. The investigators knew of no way to contain the contamination—to halt its advance. All this was bad enough, but the most mysterious and probably, in the long run, the most significant feature of the whole episode was the discovery of 2,4-D in the holding ponds of the arsenal, even though no 2,4-D had been manufactured there during any stage of operations. After long and careful study, the chemists at the plant concluded that the 2,4-D had been formed spontaneously in the holding ponds, from other substances discharged from the arsenal; in the presence of catalyzing air and sunlight, and quite without the intervention of human chemists, the ponds had become laboratories for the production of a new chemical.

Indeed, one of the most alarming aspects of the chemical pollution of water is the fact that in river or lake or reservoir—or, for that matter, in the glass of water served at your dinner table—are mingled chemicals that no responsible chemist would think of combining in his laboratory. The possible interactions between these chemicals, often comparatively harmless in themselves, are deeply disturbing to officials of the United States Public Health Service. The reactions may take place between two or more chemicals, or between various chemicals and radioactive wastes. Under the impact of ionizing radiation, rearrangements of atoms could easily occur, changing the nature of the chemical in a wholly unpredictable way, and one that would be wholly beyond control.

A striking example of the contamination of surface waters seems to be building up in the National Wildlife Refuges at Tule Lake and Lower Klamath Lake, both in California. These refuges are part of a group, which also includes the refuge on Upper Klamath Lake, just over the border in Oregon. The three are linked, perhaps fatefully, by a shared water supply, and they lie like small islands in a great sea of surrounding farmlands—land reclaimed by drainage and stream diversion from an original waterfowl paradise of marsh and open water. These farmlands around the refuges are now irrigated by water from Upper Klamath Lake. The irrigation waters, having been re-collected from the fields they have served, are pumped into Tule Lake and from there into Lower Klamath Lake. In the summer of 1960, biologists picked up hundreds of dead and dying birds at Tule Lake and Lower Klamath Lake. Most of them were fish-eating species—herons, pelicans, grebes, gulls. Upon analysis, they were found to contain insecticide residues identified as the chlorinated hydrocarbons toxaphene, DDD, and DDE. Fish from the lakes were also found to contain the insecticide residues; so were samples of plankton. It appears that pesticide residues are now building up in the waters of these refuges, being conveyed there by return irrigation flow from heavily sprayed agricultural lands. The refuges are critically important to the conservation of Western waterfowl. They lie in a strip of territory corresponding to the narrow neck of a funnel, in

which all the migratory paths constituting what is known as the Pacific Flyway converge. During the fall migration, the three refuges receive many millions of ducks and geese, from nesting grounds that extend from the shores of the Bering Sea east to Hudson Bay—in fact, fully three-fourths of all the waterfowl that move south into or through the Pacific Coast states in autumn. During the summer, the refuges provide nesting areas for waterfowl, and especially for two endangered species, the redhead and the ruddy duck. If the lakes and pools of these refuges become seriously contaminated, the damage to the waterfowl populations of the Far West could be irreparable.

Water, of course, supports long chains of life—from the small-as-dust green cells of the drifting plant plankton, through the minute water fleas, to the fish that strain plankton from the water and are, in turn, eaten by other fish or by birds, mink, raccoons, and man himself, in an endless transfer of materials from life to life. We know that the minerals necessary for all these forms of life are extracted from the water and passed from link to link of the food chains. Can we suppose that poisons we introduce into water will not follow the same course? The answer is to be found in the recent history of Clear Lake, California. Clear Lake lies in mountainous country some ninety miles north of San Francisco and has long been popular with anglers. The name is plainly inappropriate; actually the lake is rather turbid, because its bottom, which is shallow, is covered with soft black ooze. Unfortunately for the fishermen and the resort dwellers on its shores, its waters have long provided an ideal habitat for a small gnat, *Chaoborus astictopus*. Although the gnat is closely related to mosquitoes, it is not a bloodsucker; indeed, it probably does not feed at all as an adult. However, the human beings who came to share its habitat found it annoying, because of its sheer numbers. Efforts were made to control it, but they were largely fruitless until, in the late nineteen-forties, the chlorinated-hydrocarbon insecticides offered a new weapon. The chemical chosen for a fresh attack was DDD, an insecticide that apparently offered fewer threats to fish life than DDT. The new control measures, undertaken in September of 1949, were carefully planned, and few people would have supposed that any harm could result. The lake was surveyed, its volume was determined, and the insecticide was applied in the concentration of one part to every seventy million parts of water. Control of the gnats was good at first, but by September of 1954 the treatment had to be repeated, and this time the chemical was added in the concentration of one part in fifty million parts of water. The destruction of the gnats was then thought to be virtually complete.

The following winter months brought the first intimation that other life was affected; the western grebes on the lake began to die, and soon more than a hundred of them had been reported dead. At Clear Lake, the western grebe is a breeding bird and also a winter visitant, attracted by the abundant fish of the lake. It is a bird of spectacular appearance and beguiling habits, building floating nests in shallow lakes of the western United States and western Canada. It is sometimes called the “swan grebe,” and with reason, for it glides with scarcely a ripple across the lake surface, its body riding low and its white neck and shining black head held high. The newly hatched chick is clothed in soft gray down; only a few hours after emerging from the shell it takes to the water, riding on the back of the father or mother, nestled under the parental wing coverts. Following a third assault on the ever-resilient gnat population, in September, 1957—again in a concentration of one part of DDD to fifty million parts of water—more grebes died. Both then and in 1954, no evidence of infectious disease could be discovered on examination of the dead birds. But when someone thought of analyzing the fatty tissues of the grebes, they were found to be loaded with DDD in the

extraordinary concentration of sixteen hundred parts per million. How could the chemical have built up to such prodigious levels? The grebes, of course, are fish eaters. When the fish of Clear Lake were also analyzed, the picture began to take form: The poison had been picked up by the smallest organisms, concentrated, and passed on to the larger ones, which concentrated it further. Plankton organisms were found to contain about five parts per million of the insecticide; plankton-eating fish had built up accumulations ranging from forty to three hundred parts per million; carnivorous species of fish had stored the most of all. One fish, a brown bullhead, had the astounding concentration of twenty-five hundred parts per million. It was a house-that-Jack-built sequence, in which the large carnivores had eaten the smaller carnivores, which had eaten the herbivores, which had eaten the plankton, which had absorbed the poison from the water.

Even more extraordinary discoveries were made later. No trace of DDD could be found in the water shortly after the last application of the chemical. But the poison had not really left the lake; it had merely gone into the fabric of the life that the lake supported. Twenty-three months after the chemical treatment had ceased, the plankton still contained as much as 5.3 parts of it per million. In that interval of nearly two years, successive crops of plankton had flowered and faded away, but the poison had somehow passed from generation to generation. And it lived on in the animal life of the lake as well. All fish, birds, and frogs examined a year after the chemical applications had ceased still contained DDD. The amount found in the flesh always exceeded by many times the original concentration in the water. Among these living carriers were fish that had hatched nine months after the last application of DDD. California gulls had built up concentrations of more than two thousand parts per million. The grebes still carried heavy residues, and meanwhile their nesting colonies had dwindled, from more than a thousand pairs before the first insecticide treatment to about thirty pairs in 1960. Even the thirty seem to have nested in vain, for no young grebes have been observed on the lake since the last DDD application. And what of the human being who has rigged his fishing tackle, caught a string of fish from the waters of Clear Lake, and taken them home to fry for supper? What could a heavy dose of DDD—and perhaps repeated heavy doses—do to him? The California State Department of Public Health professed to see no hazard, yet in 1959 it required that the use of DDD in the lake be stopped. In view of the evidence, the action seems a minimum safety measure.

The thin layer of soil that forms a patchy covering over the continents controls our own existence and that of every other animal of the land. Without soil, land plants as we know them could not grow, and without plants no animal could survive. Yet if our life depends on the soil, it is equally true that soil depends on life; its very origins and the maintenance of its true nature are intimately related to living plants and animals. For soil is in part a creation of life, born of a marvellous interaction of life and inert matter aeons ago. The parent materials were gathered together as volcanoes poured them out in fiery streams, as waters running over the bare rocks of the continents wore away even the hardest granite, and as the chisels of frost and ice split and shattered the rocks. Then living things began to work their creative magic, and little by little these inert materials became soil. Lichens, the rocks' first covering, aided the process of disintegration by means of acid secretions and made a lodging place for other life. Mosses took hold in these little pockets of simple soil—soil formed by crumbling bits of lichen, by the husks of minute insect life, by the debris of a fauna beginning its emergence from the sea. And not only did life help form the soil

but living things now exist within it in incredible abundance and diversity; if this were not so, the soil would be a dead and sterile thing. The soil exists in a state of constant change, taking part in cycles that have no beginning and no end. New materials are constantly being contributed as rocks disintegrate, as organic matter decays, and as nitrogen and other gases are brought down in rain from the skies. Simultaneously, materials are being taken away, harrowed temporarily for use by living creatures. Subtle and vastly important chemical changes are constantly in progress, converting elements derived from air and water into forms suitable for the support of plant life, and in all these changes living organisms are active agents.

There are few studies more fascinating, and at the same time more neglected, than the study of the teeming populations that exist in the dark realms of the soil. We know too little of the links that bind the soil organisms to each other, to their world, and to the world above. Perhaps the most essential organisms in the soil are the smallest—the invisible hosts of bacteria and of threadlike fungi. Statistics of their abundance take us at once into astronomical figures. A teaspoonful of topsoil may contain billions of bacteria. In spite of their minute size, the combined weight of bacteria in the top foot of a single acre of fertile soil, which itself weighs from ten to seventeen tons, may be as much as a thousand pounds. Ray fungi, growing in long filaments, are somewhat less numerous than the bacteria, but since they are larger, their total weight in a given amount of soil may be about the same. With small, green cells of algae, these make up the microscopic plant life of the soil. Bacteria, fungi, and algae are the principal agents of decay, reducing plant and animal residues to their component materials. The vast cyclic movements of chemical elements, such as carbon and nitrogen, through soil and air and living tissue could not proceed without these microplants. Without the nitrogen-fixing bacteria, for example, plants would starve for want of nitrogen, though they are surrounded by nitrogen-containing air. Other soil organisms form carbon dioxide, which on being dissolved in water becomes carbonic acid and aids in dissolving rock. Still other soil microbes perform the various oxidations and reductions by which minerals such as iron, manganese, and sulphur are transformed and made available to plants. Also present in prodigious numbers in the soil are microscopic mites and primitive, wingless insects called springtails. Small as they are, both play an important part in breaking down the residues of plants, and thus aid in the slow conversion of the litter of the forest floor to soil. The specialization of some of these minute creatures for their task is almost incredible. Several species of mites, for example, can begin life only within needles that have fallen from a spruce tree. Sheltered there, they digest out the inner tissues of the needle. By the time the mites have completed their development, only the outer layer of cells remains. The truly staggering task of dealing with the tremendous amount of plant material in the annual leaf fall belongs to some of the small insects of the soil and the forest floor. They macerate and digest the leaves, and help to mix the decomposed matter with the surface soil.

Besides all this horde of minute but ceaselessly toiling creatures, there are, of course, many larger forms, for soil life runs the gamut from bacteria to mammals. Some of these larger forms are permanent residents of the dark, subsurface layers; some hibernate or spend certain parts of their life cycles in underground chambers; some come and go freely between their burrows and the upper world. In general, the effect of all this habitation of the soil is to aerate it and to improve both its drainage and the penetration of water throughout the layers of plant growth. Of all the larger inhabitants of the soil, probably none is more important than the earthworm. Just over three-quarters of a century ago, Charles Darwin published a book titled “The Formation of Vegetable

Mould Through the Action of Worms, with Observations on Their Habits.” In it he gave the world its first understanding of the fundamental role that earthworms play as geological agents for the transport of soil—a picture of surface rocks being gradually covered by fine soil brought up from below by the worms, which ingest earth in building burrows and as food and eject it near the surface in annual amounts running to many tons to the acre in the most favorable areas. At the same time, they draw quantities of organic matter contained in leaves and grass—as much as twenty pounds to the square yard in six months—down into the burrows, where they become part of the soil. Darwin’s calculations showed that the toil of earthworms might produce a layer of soil from an inch to an inch and a half thick in a ten-year period. This is by no means all they do. Their burrows aerate the soil, keep it well drained, and aid the penetration of plant roots. And organic matter is broken down as it passes through their digestive tracts, so the soil is enriched by their excretory products.

What happens to the inhabitants of the soil when poisonous chemicals are carried down into their world, either introduced directly as soil “sterilants” or sprayed on crops or borne by rain that has picked up a lethal contamination as it filtered through the leaf canopy of forest and orchard and cropland? Is it reasonable to suppose that a so-called broad-spectrum insecticide can kill the burrowing larval stages of a crop-destroying insect without also killing the insects whose function may be the essential one of breaking down organic matter? Or can we use a non-specific fungicide in orchards without also killing the fungi that inhabit the roots of many trees and aid the tree in extracting nutrients from the soil? The plain truth is that this critically important subject of the ecology of the soil has been largely neglected even by scientists and almost completely ignored by control men. The chemical control of insects seems to have proceeded on the assumption that the soil could and would sustain any amount of insult without striking back. From the few studies that have been made, a picture of the impact of pesticides on the soil is slowly emerging. The studies are not always in agreement, for soil types vary enormously and what causes damage in one may be innocuous in another. Light, sandy soils suffer far more heavily than humus types, for example, and combinations of chemicals often seem to do more harm than separate applications. Despite the varying results, enough solid evidence of harm is accumulating to cause apprehension on the part of the scientists concerned.

Under some conditions, the chemical conversions and transformations that lie at the very heart of the living world are affected. For example, the herbicide 2,4-D causes a temporary interruption of nitrification. Recent experiments in Florida showed that three chlorinated hydrocarbons—heptachlor, BHC (benzene hexachloride), and lindane, which is an isomer of BHC—reduced nitrification after only two weeks in the soil; BHC and DDT had significantly detrimental effects a year after treatment. In other experiments, it was found that BHC, lindane, aldrin, heptachlor, and DDD all prevented nitrogen-fixing bacteria from forming the necessary root nodules on leguminous plants, and also that a curious but beneficial relation between fungi and the roots of higher plants was seriously disrupted. Sometimes the problem is one of upsetting that delicate balance of populations by which nature accomplishes far-reaching aims. Explosive increases in certain kinds of soil organisms have occurred when other kinds have been reduced by insecticides, disturbing the relation of predator to prey. Such changes could easily alter the metabolic activity of the soil and affect its productivity. They could also mean that potentially harmful organisms, formerly held in check, might take on the status of pests.

One of the most important things to remember about insecticides in soil is their persistence. Aldrin has been recovered after four years, both as traces and, more abundantly, as converted to dieldrin. Ten years after the application of toxaphene to sandy soil, enough remains to kill termites. BHC persists a least eleven years, and heptachlor at least nine. Chlordane has been recovered after twelve years. Seemingly moderate applications of insecticides over a period of years may build up fantastic quantities in soil. The legend that “a pound of DDT to the acre is harmless” means nothing if spraying is repeated. Potato soils have been found to contain up to fifteen pounds of DDT per acre, corn soils up to nineteen. A cranberry bog under study contained thirty-four and a half pounds to the acre. Soils from apple orchards seem to reach the peak of contamination, for the rate at which DDT accumulates here almost keeps pace with its rate of annual application. In a single season, if orchards are sprayed four or more times, DDT residues may amount to as much as fifty pounds to the acre. Arsenic provides a classic instance of the virtually permanent poisoning of the soil. Although since the mid-forties arsenic as a spray on growing tobacco has been largely replaced by the synthetic insecticides, the arsenic content of cigarettes made from American-grown tobacco increased more than three hundred per cent between the years 1932 and 1962. Dr. Henry S. Satterlee, an authority on arsenic toxicology, says that the soils of tobacco plantations are now thoroughly impregnated with arsenic residues in the form of a heavy and relatively insoluble poison, arsenate of lead. This will continue to release arsenic in soluble form. As Dr. Satterlee puts it, the soil of a large proportion of the land planted with tobacco has been subjected to “cumulative and well-nigh permanent poisoning.” Tobacco grown in the eastern Mediterranean countries, where arsenical insecticides are not used, has shown no such increase in arsenic content.

The question arises to what extent insecticides are absorbed into plant tissues from contaminated soils. Much depends on the type of soil, the crop, and the nature and the concentration of the insecticide. Soils high in organic matter release smaller quantities of poisons than others do. Carrots absorb more insecticide than any other crop studied; if the insecticide used happens to be lindane, carrots actually accumulate higher concentrations than are present in the soil. In the future, it may become necessary to analyze soils for insecticides before planting certain food crops. Otherwise, unsprayed crops may take up enough insecticide from the soil to render them unfit for market. This very sort of contamination has already created endless problems for at least one leading manufacturer of baby foods, who has been unwilling to buy any fruits or vegetables that have been exposed to insecticides. The chemical that caused him the most trouble was BHC, which is taken up by the roots and tubers of plants, and which advertises its presence by a musty taste and odor. Sweet potatoes grown in California fields where BHC had been used two years earlier contained residues, and the firm had to reject them. Another year, in which the firm had contracted for its total requirements of sweet potatoes with growers in South Carolina, so large a proportion of the acreage was found to be contaminated that the company was forced to buy in the open market, at a considerable financial loss. The manufacturer’s most stubborn problem has been with peanuts. In the Southern states, peanuts are usually grown in rotation with cotton, on which BHC is extensively used, and the peanuts pick up considerable amounts of the insecticide. Actually, only a trace is enough to give them the telltale musty odor and taste. The chemical penetrates the nuts and cannot be removed.

Sometimes the menace is to the crop itself—a menace as long-lasting as the insecticide contamination of the soil. Some insecticides affect sensitive plants such as beans, wheat, barley, and rye, retarding root development or inhibiting the growth of seedlings. The experience of the

hop growers of Washington and Idaho is an example. During the spring of 1955, many of these growers undertook a large-scale program to control the strawberry-root weevil, whose larvae had become abundant on the roots of the hops. On the advice of agricultural experts and insecticide manufacturers, they chose heptachlor to do the job. Within a year after the heptachlor was applied, in both dust and spray forms, the vines in the treated yards were wilting and dying. In the untreated fields there was no trouble; in fact, the damage stopped at the border between treated and untreated fields. The fields were replanted, at great expense, but the next year the new roots, too, were found to be dead. Four years later, the soil still contained heptachlor, and scientists were unable to predict how long it would remain poisonous, or to recommend any procedure for correcting the condition. The United States Department of Agriculture, which as late as March, 1959, had declared heptachlor to be acceptable for use on hops in the form of a soil treatment, thereafter belatedly withdrew its registration for such use. Meanwhile, the hop growers sought what redress they could in the courts.

In continuing to contaminate the soil, we are almost certainly headed for trouble. This was the consensus of a groups of specialists who met in 1960 at the College of Forestry of the State University of New York, in Syracuse, to discuss the ecology of the soil. These men summed up the hazards of using “such potent and little understood tools” as chemicals and radioactive substances: “A few false moves on the part of man may result in destruction of soil productivity and the arthropods may well take over.”

Water, soil, and the earth’s green mantle of plants make up the world that supports the animal life of the earth. Although modern man seldom remembers the fact, he could not exist without the plants that harness the sun’s energy and manufacture the basic foodstuffs he depends upon for life. Our attitude toward plants is a singularly narrow one. If we see any immediate utility in a plant, we foster it. If, for any reason, we find its presence undesirable, or even simply a matter of indifference, we may condemn it to destruction forthwith. Besides the various plants that are poisonous to man or his livestock, or crowd out food plants, many are marked for destruction merely because they happen to be in the wrong place at the wrong time, and many others are destroyed merely because they happen to be associates of the unwanted plants. Sometimes we have no choice but to disturb the relationships between plants and the earth, between plants and other plants, and between plants and animals, yet we should do so thoughtfully, with full awareness that what we do may have consequences remote in time and place.

One example of our unthinking bludgeoning of the landscape is to be seen in the sagebrush lands of the West, where a vast campaign has been launched to destroy the sage and substitute grass. If ever an enterprise needed to be illuminated with a sense of the history and meaning of the landscape, it is this one. For here the natural landscape is eloquent of the interplay of forces that have created it. It is spread before us like the pages of an open book, telling why the land is what it is, and why we should preserve its integrity. But the pages lie unread. The land of the sage is the land of the high Western plains and the lower slopes of the mountains that rise above them—a land born of the uplift of the Rocky Mountain system many millions of years ago. It is a place of harsh extremes of climate: of long winters when blizzards drive down from the mountains and snow lies thick on the plains, of summers whose heat is relieved only by scanty rains, with drought biting

deep into the soil, and dry winds stealing moisture from leaf and stem. In the evolution of this landscape, there must have been a long period of trial and error as plants attempted the colonization of the high and wind-swept land. One after another must have failed. At last, a group of plants took root that combined all the qualities needed for survival. The sage—low-growing and shrubby—could maintain its hold on the mountain slopes and on the plains, and within its small gray leaves it could store moisture enough to defy the thieving winds. It was no accident but, rather, the result of long ages of experimentation by nature that the great plains of the West became the land of the sage.

Along with the plants, animal life was evolving in harmony with the searching requirements of the land. In time there were two animals as well adjusted to their habitat as the sage. One was a mammal, the fleet and graceful pronghorn antelope. The other was a bird, the sage grouse—the “cock of the plains” of Lewis and Clark. The sage and the grouse seem made for each other. The range of the bird coincides with the range of the sage, and the sage is all things to these birds of the plains. The low sage of the foothill ranges shelters their nests and their young; the denser growths are loafing and roosting areas; at all times the sage provides the staple food of the grouse. Yet it is a two-way relationship. The spectacular courtship displays of the cocks help loosen the soil beneath and around the sage, aiding invasion by grasses that can grow in the shelter of the sagebrush. The antelope, too, have adjusted their lives to the sage. Though some of them summer in the mountains, they are primarily animals of the plains, and in winter, when the first snows come, they all seek the lower elevations. There the sage provides the food that tides them over the winter. Where all other plants have shed their leaves, the gray-green leaves of the sage—bitter, aromatic, rich in proteins, fats, and needed minerals—cling to the stems of the densely growing plants. Though the snows pile up, the tops of the sage remain exposed, or can be reached by the sharp, pawing hoofs of the antelope. Then grouse feed on them, too, finding them on bare and windswept ledges or following the antelope to spots where they have scratched away the snow. Other life also looks to the sage. Mule deer often feed on it. Sage may mean survival to winter-grazing livestock. Sheep graze many winter ranges where the big sage brush forms almost pure stands. For half the year, it is their principal forage, and it is a plant of higher energy value than even alfalfa hay.

The upland plains, the purple wastes of sage, the wild, swift antelope, and the grouse are then a natural system in perfect balance. Or, rather, in many places, there was such a balance. In recent years, the land-management agencies have set about satisfying the insatiable demands of the cattlemen for more grazing land. By this they mean grassland—grass without sage. Few seem to have asked whether grassland is a stable and desirable goal in the region. Certainly nature’s own answer was no. The annual precipitation in this land is not enough to support good sod-forming grass; rather, it favors the bunch grass that grows in the shelter of the sage. Yet millions of acres of sagebrush lands are sprayed each year. What are the results? The long-term effects of eliminating sage and seeding with grass are largely conjectural. Men of long experience in the ways of the land say that in this country there is better growth of grass between and under the moisture-holding sage than can possibly be had in pure stands. But even if the program succeeds in its immediate objective, it is clear that the whole closely knit fabric of life is being ripped apart. The antelope and the grouse will disappear, along with the sage. Even the livestock, which are the intended beneficiaries, will suffer; no amount of lush green grass in summer can help the sheep starving in the winter storms for lack of the sage and bitter brush and other wild vegetation of the

plains. These are the first and obvious effects. Others are of the kind that is always associated with the shotgun approach to nature: the spraying also eliminates a great many plants that were not its intended target. Justice William O. Douglas, in his recent book "My Wilderness: East to Katahdin," has told of an example of ecological destruction wrought by the Forest Service in the Bridger National Forest, in Wyoming. Yielding to the pressure of cattlemen for more grassland, the Service sprayed some ten thousand acres of sage lands. The sage was killed, as was intended. But so was a green, life-giving ribbon of willows that traced its way across these plains, following the meandering streams. Moose had lived in these willow thickets, for willow is to the moose what sage is to the antelope. Beavers had lived there, too, feeding on the willows, felling them, and making strong dams across the tiny streams. Through the labor of the beavers, a lake backed up. Trout in the mountain streams were seldom more than six inches long; in the lake they thrived so prodigiously that many grew to five pounds. Waterfowl were attracted to the lake. But with the "improvement" instituted by the Forest Service, the willows went the way of the sagebrush, killed by the same, impartial spray. When Justice Douglas visited the area in 1959, the year of the spraying, he was shocked to see the shrivelled and dying willows—the "vast, incredible damage." What would become of the moose? Of the beavers and the little world they had constructed? A year later, he returned to read the answers in the devastated landscape. The moose were gone, and so were the beavers. The principal beaver dam had gone out for want of attention by its skilled architects, and the lake had drained away. None of the large trout were left, for none could live in the tiny creek that remained, threading its way through a bare, hot land.

Besides the more than four million acres of range lands sprayed each year, large areas of other types of land are potential or actual recipients of chemical treatments for weed control. For example, in the United States an area larger than all of New England—some fifty million acres—is under the management of utility corporations, and much of it is routinely treated for "brush control." In the Southwest, an estimated seventy-five million acres of mesquite lands require management by some means, and chemical spraying is the method most actively pushed. An unknown but very large acreage of timber-producing lands is now aerially sprayed for the purpose of "weeding out" the hardwoods from the more spray-resistant conifers. Added to these are an estimated fifty-three million acres of agricultural lands, perhaps two million acres of non-crop lands, and countless private lawns, parks, and golf courses, the combined acreage of which must reach an extremely large figure. And besides all this, there are our roadsides.

Roadside brush control is practiced in all parts of the country, with the object of eliminating plants that ultimately grow tall enough to obstruct drivers' vision or to interfere with wires on rights of way. This is a legitimate object, but as roadside spraying is commonly carried out, it has many undesirable side effects. One of them is economic. The town fathers of a thousand communities lend willing ears to the chemical salesmen and the eager contractors who will rid their roadsides of "brush." Spraying, they are told, is cheaper than mowing. So, perhaps, it appears in the neat rows of figures in the official books, but were the true cost entered, the wholesale broadcasting of chemicals would be seen to be far more expensive, both in dollars and in the infinite damage it does. Take, for example, a commodity that is prized by every chamber of commerce throughout the land—the good will of vacationing tourists. There is a steadily growing chorus of outraged protest at the disfigurement of once beautiful roadsides by chemical sprays. "We are making a dirty, brown, dying-looking mess along the sides of our roads," a New England woman wrote angrily to her local newspaper last fall. "This is not what the tourists expect, with all the money

we are spending advertising the beautiful scenery.” In the summer of 1960, conservationists from many states converged on a beautiful Maine island to witness its presentation to the National Audubon Society by its owner, Millicent Todd Bingham. The focus that day was on the preservation of the natural landscape, with its intricate web of life whose interwoven strands lead from microbe to man. But in the background of all the conversations among the visitors to the island was indignation at the despoiling of the roads they had travelled to reach it. Once, it had been a joy to follow those roads through the evergreen forests—roads lined with bayberry and sweet fern, alder and huckleberry. Now all was brown desolation. One of the conservationists wrote of that summer pilgrimage, “I returned . . . angry at the desecration of the Maine roadsides. Where, in previous years, the highways were bordered with wild flowers and attractive shrubs, there were only the scars of dead vegetation for mile after mile. . . . As an economic proposition, can Maine afford the loss of tourist good will that such sights induce?”

Botanists at the Connecticut Arboretum, in New London, declare that the elimination of beautiful native shrubs and wild flowers has reached the proportions of a “roadside crisis.” Azaleas, mountain laurel, blueberry, huckleberry, viburnum, dogwood, hayberry, sweet fern, low shadbush, winterberry, chokecherry, and wild plum are dying under the chemical barrage. So are the daisies, the black-eyed Susans, the Queen Anne’s lace, the goldenrod, and the fall asters. In the spring of 1957, trees within the Connecticut Arboretum Natural Area were seriously injured when the town of Waterford sprayed the roadsides with chemical weed killers. Even large trees not directly sprayed were affected. The leaves of the oaks began to curl and turn brown, although it was the season for spring growth. Then new shoots appeared, and these grew with abnormal rapidity, giving a “weeping” appearance to the trees. Two seasons later, large branches on some of these trees had died, other branches were without leaves, and the deformed, weeping effect of whole trees persisted.

I know well a stretch of road where nature’s own landscaping once provided a border of alder, viburnum, sweet fern, and juniper, with seasonally changing accents of bright flowers, and of fruits hanging in jewelled clusters in the fall. The road had no heavy load of traffic to support, and there were few sharp curves or intersections where brush could obstruct the driver’s vision. Nevertheless, the sprayers took over, and the miles along that road became something to be traversed quickly, a sight to be endured with one’s mind closed to thoughts of the sterile and hideous world we are letting our technicians make. Here and there, though, authority had faltered, and by an unaccountable oversight there were oases of beauty—oases that made the desecration of the greater part of the road the more unbearable. In such places, my spirit lifted to the sight of the drifts of white clover or the clouds of purple vetch, with here and there the flaming cup of a wood lily. Such plants are “weeds” only to those who make a business of selling and applying weed killers.

There is, of course, more to the wish to preserve our roadside vegetation than aesthetic considerations. In the economy of nature, the natural vegetation has its essential place. Hedgerows along country roads and the edges of fields provide food, cover, and nesting areas for birds and homes for many small animals; indeed, of some seventy species of shrubs and vines that are typical roadside species, about sixty-five are important to wildlife as food. Such vegetation is also the habitat of wild bees and other pollinating insects. Man is more dependent on these wild pollinators than he usually realizes. Even the farmer seldom understands the value of wild bees, and often

participates in measures that rob him of their services. Not only many wild plants but some agricultural crops are partly or wholly dependent on the services of the native pollinating insects; several hundred species of wild bees take part in the pollination of cultivated crops—a hundred species visiting the flowers of alfalfa alone. Moreover, in the absence of insect pollination, most of the soil-holding and soil-enriching plants of uncultivated areas would die out, with far-reaching consequences for the ecology of the whole region. A great variety of herbs, shrubs, and trees of our forests and ranges depend on native insects for their reproduction, and without these plants many wild animals and much range stock would find little food. Now “clean” cultivation and the chemical spraying of hedgerows and weeds, including some of those that bees depend upon heavily for food, are eliminating the last sanctuaries of these pollinating insects and thereby breaking the threads that bind life to life. The bees, so essential to our agriculture and indeed to our landscape as we know it, deserve something better from us than the senseless destruction of their habitat.

Ironically, the all-out chemical assault perpetuates the problems it seeks to correct. Ragweed, the bane of hayfever sufferers, offers an interesting example of the way efforts to control nature sometimes boomerang. Many thousands of gallons of chemicals have been discharged along roadsides in the name of ragweed control, but the unfortunate truth is that blanket spraying is resulting in more ragweed, not less. Ragweed is an annual; each year its seedlings require open soil in order to become established. Our best protection against this plant is therefore the maintenance of dense shrubs and ferns and other perennial vegetation. Spraying destroys this protective vegetation and creates open, barren areas, which the ragweed hastens to fill.

Just as ironically, some spraying actually creates new problems. The chemical 2,4-D, by killing out the broad-leaved plants, allows the grasses to thrive, and now some of the grasses themselves have become “weeds,” presenting a new problem of control and giving the cycle another turn. This situation is acknowledged in a recent issue of a technical journal devoted to crop problems, which notes that “with the widespread use of 2,4-D to control broad-leaved weeds, grass weeds in particular have increasingly become a threat to corn and soybean yields.”

We persist in this inefficient approach despite the fact that a perfectly sound method of selective spraying is known, which can achieve long-term vegetational control and eliminate repeated spraying of most types of vegetation. Selective spraying was developed by Dr. Frank Egler, a plant ecologist who was for some years associated with the American Museum of Natural History and who is the chairman of a Committee for Brush Control Recommendations for Rights of Way. The method he devised takes advantage of the fact that the best and cheapest controls for vegetation are not chemicals but other plants. Trees find it difficult to gain a foothold in a community of shrubs, and on roadsides most shrubs, and all ferns and wild flowers, are low enough to present no hazard to drivers and no obstruction to wires. Selective spraying, in contrast to blanket spraying, is directed only at trees and exceptionally tall shrubs, the poison being applied at the base. (Cutting down a tree is seldom a permanent solution, because many trees will grow again.) One spraying may be sufficient to eliminate such trees and shrubs, with a possible followup for extremely resistant species; thereafter the shrubs assert control and the trees do not return. Dr. Egler has under observation shrub communities that have remained stable, without return of trees, for a quarter of a century after selective spraying. The spraying can often be done by men on foot, with knapsack sprayers, which give them complete control over their material. Sometimes tanks and compressor pumps can be mounted on truck chassis, but there is still no blanket spraying. The integrity of the

environment is thereby preserved, the enormous value of the wildlife habitat remains intact, and the beauty of shrub and fern and the rest of the roadside growth has not been sacrificed. The method of vegetation management by selective spraying has been adopted by the authorities in some areas. All other considerations aside, when more taxpayers understand that the bill for spraying the town roads should come due only once a generation instead of once a year, they will surely rise up and demand a change of method.

The chemical pesticides are a bright new toy. They sometimes work in a spectacular way, giving those who wield them a giddy sense of power over nature, and as for the failures and the long-range undesirable effects, these are dismissed as the baseless imaginings of pessimists. Disregarding the whole record of contamination and death, we continue to spray, and to spray indiscriminately. We proceed as if there were no alternative, even though there are alternatives, such as biological controls and selective spraying, which have been effective in many places. As Dr. C. J. Briejèr, a Dutch scientist of rare understanding, has put it, "We are walking in nature like an elephant in the china cabinet." ♦

This article appears in the print edition of the [June 16, 1962](#), issue.

Rachel Carson is the author of the best-seller "Silent Spring" and "The Sea Around Us," which won the National Book Award for nonfiction. She was posthumously awarded the Presidential Medal of Freedom in 1980.

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