SILENT SPRING

The CLASSIC *that* LAUNCHED *the* ENVIRONMENTAL MOVEMENT

RACHEL CARSON

Introduction by **LINDA LEAR** // *Afterword by* **EDWARD O. WILSON**

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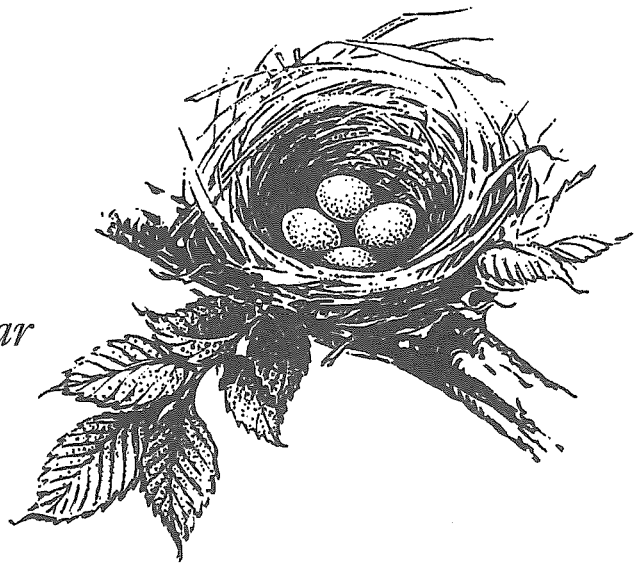

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To Albert Schweitzer
who said

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

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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 skeptically and dictatorially.

E. B. WHITE

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.

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Introduction

by Linda Lear

HEADLINES IN THE *New York Times* in July 1962 captured the national sentiment: "*Silent Spring* is now noisy summer." In the few months between the *New Yorker*'s serialization of *Silent Spring* in June and its publication in book form that September, Rachel Carson's alarm touched off a national debate on the use of chemical pesticides, the responsibility of science, and the limits of technological progress. When Carson died barely eighteen months later in the spring of 1964, at the age of fifty-six, she had set in motion a course of events that would result in a ban on the domestic production of DDT and the creation of a grass-roots movement demanding protection of the environment through state and federal regulation. Carson's writing initiated a transformation in the relationship between humans and the natural world and stirred an awakening of public environmental consciousness.

It is hard to remember the cultural climate that greeted *Silent Spring* and to understand the fury that was launched against its quietly determined author. Carson's thesis that we were subjecting ourselves to slow poisoning by the misuse of chemical pesticides that polluted the environment may seem like common currency now, but in 1962 *Silent Spring* contained the kernel of social revolution. Carson wrote at a time of new affluence and intense social conformity. The cold war, with its climate of suspicion and intolerance, was at its zenith. The chemical industry, one of the chief beneficiaries of postwar technology, was also one of the chief authors of the nation's prosperity. DDT enabled the conquest of insect pests in agriculture and of ancient insect-borne disease just as surely as the atomic bomb destroyed Amer-

ica's military enemies and dramatically altered the balance of power between humans and nature. The public endowed chemists, at work in their starched white coats in remote laboratories, with almost divine wisdom. The results of their labors were gilded with the presumption of beneficence. In postwar America, science was god, and science was male.

Carson was an outsider who had never been part of the scientific establishment, first because she was a woman but also because her chosen field, biology, was held in low esteem in the nuclear age. Her career path was nontraditional; she had no academic affiliation, no institutional voice. She deliberately wrote for the public rather than for a narrow scientific audience. For anyone else, such independence would have been an enormous detriment. But by the time *Silent Spring* was published, Carson's outsider status had become a distinct advantage. As the science establishment would discover, it was impossible to dismiss her.

Rachel Carson first discovered nature in the company of her mother, a devotee of the nature study movement. She wandered the banks of the Allegheny River in the pristine village of Springdale, Pennsylvania, just north of Pittsburgh, observing the wildlife and plants around her and particularly curious about the habits of birds.

Her childhood, though isolated by poverty and family turmoil, was not lonely. She loved to read and displayed an obvious talent for writing, publishing her first story in a children's literary magazine at the age of ten. By the time she entered Pennsylvania College for Women (now Chatham College), she had read widely in the English Romantic tradition and had articulated a personal sense of mission, her "vision splendid." A dynamic female zoology professor expanded her intellectual horizons by urging her to take the daring step of majoring in biology rather than English. In doing so, Carson discovered that science not only engaged her mind but gave her "something to write about."

She decided to pursue a career in science, aware that in the 1930s there were few opportunities for women.

Scholarships allowed her to study at Woods Hole Biological Laboratory, where she fell in love with the sea, and at Johns Hopkins University, where she was isolated, one of a handful of women in marine biology. She had no mentors and no money to continue in graduate school after completing an M.A. in zoology in 1932. Along the way she worked as a laboratory assistant in the school of public health, where she was lucky enough to receive some training in experimental genetics. As employment opportunities in science dwindled, she began writing articles about the natural history of Chesapeake Bay for the *Baltimore Sun*. Although these were years of financial and emotional struggle, Carson realized that she did not have to choose between science and writing, that she had the talent to do both.

From childhood on, Carson was interested in the long history of the earth, in its patterns and rhythms, its ancient seas, its evolving life forms. She was an ecologist—fascinated by intersections and connections but always aware of the whole—before that perspective was accorded scholarly legitimacy. A fossil shell she found while digging in the hills above the Allegheny as a little girl prompted questions about the creatures of the oceans that had once covered the area. At Johns Hopkins, an experiment with changes in the salinity of water in an eel tank prompted her to study the life cycle of those ancient fish that migrate from continental rivers to the Sargasso Sea. The desire to understand the sea from a nonhuman perspective led to her first book, *Under the Sea-Wind*, which featured a common sea bird, the sanderling, whose life cycle, driven by ancestral instincts, the rhythms of the tides, and the search for food, involves an arduous journey from Patagonia to the Arctic Circle. From the outset Carson acknowledged her "kinship with other forms of life" and always wrote to impress that relationship on her readers.

Carson was confronted with the problem of environmental

pollution at a formative period in her life. During her adolescence the second wave of the industrial revolution was turning the Pittsburgh area into the iron and steel capital of the Western world. The little town of Springdale, sandwiched between two huge coal-fired electric plants, was transformed into a grimy wasteland, its air fouled by chemical emissions, its river polluted by industrial waste. Carson could not wait to escape. She observed that the captains of industry took no notice of the defilement of her hometown and no responsibility for it. The experience made her forever suspicious of promises of "better living through chemistry" and of claims that technology would create a progressively brighter future.

In 1936 Carson landed a job as a part-time writer of radio scripts on ocean life for the federal Bureau of Fisheries in Baltimore. By night she wrote freelance articles for the *Sun* describing the pollution of the oyster beds of the Chesapeake by industrial runoff; she urged changes in oyster seeding and dredging practices and political regulation of the effluents pouring into the bay. She signed her articles "R. L. Carson," hoping that readers would assume that the writer was male and thus take her science seriously.

A year later Carson became a junior aquatic biologist for the Bureau of Fisheries, one of only two professional women there, and began a slow but steady advance through the ranks of the agency, which became the U.S. Fish and Wildlife Service in 1939. Her literary talents were quickly recognized, and she was assigned to edit other scientists' field reports, a task she turned into an opportunity to broaden her scientific knowledge, deepen her connection with nature, and observe the making of science policy. By 1949 Carson was editor in chief of all the agency's publications, writing her own distinguished series on the new U.S wildlife refuge system and participating in interagency conferences on the latest developments in science and technology.

Her government responsibilities slowed the pace of her own

writing. It took her ten years to synthesize the latest research on oceanography, but her perseverance paid off. She became an overnight literary celebrity when *The Sea Around Us* was first serialized in *The New Yorker* in 1951. The book won many awards, including the National Book Award for nonfiction, and Carson was elected to the American Academy of Arts and Letters. She was lauded not only for her scientific expertise and synthesis of wide-ranging material but also for her lyrical, poetic voice. *The Sea Around Us* and its best-selling successor, *The Edge of the Sea*, made Rachel Carson the foremost science writer in America. She understood that there was a deep need for writers who could report on and interpret the natural world. Readers around the world found comfort in her clear explanations of complex science, her description of the creation of the seas, and her obvious love of the wonders of nature. Hers was a trusted voice in a world riddled by uncertainty.

Whenever she spoke in public, however, she took notice of ominous new trends. "Intoxicated with a sense of his own power," she wrote, "[mankind] seems to be going farther and farther into more experiments for the destruction of himself and his world." Technology, she feared, was moving on a faster trajectory than mankind's sense of moral responsibility. In 1945 she tried to interest *Reader's Digest* in the alarming evidence of environmental damage from the widespread use of the new synthetic chemical DDT and other long-lasting agricultural pesticides. By 1957 Carson believed that these chemicals were potentially harmful to the long-term health of the whole biota. The pollution of the environment by the profligate use of toxic chemicals was the ultimate act of human hubris, a product of ignorance and greed that she felt compelled to bear witness against. She insisted that what science conceived and technology made possible must first be judged for its safety and benefit to the "whole stream of life." "There would be no peace for me, she wrote to a friend, "if I kept silent."

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Silent Spring, the product of her unrest, deliberately challenged the wisdom of a government that allowed toxic chemicals to be put into the environment before knowing the long-term consequences of their use. Writing in language that everyone could understand and cleverly using the public's knowledge of atomic fallout as a reference point, Carson described how chlorinated hydrocarbons and organic phosphorus insecticides altered the cellular processes of plants, animals, and, by implication, humans. Science and technology, she charged, had become the handmaidens of the chemical industry's rush for profits and control of markets. Rather than protecting the public from potential harm, the government not only gave its approval to these new products but did so without establishing any mechanism of accountability. Carson questioned the moral right of government to leave its citizens unprotected from substances they could neither physically avoid nor publicly question. Such callous arrogance could end only in the destruction of the living world. "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?" she asked. "They should not be called 'insecticides' but 'biocides.'"

In *Silent Spring*, and later in testimony before a congressional committee, Carson asserted that one of the most basic human rights must surely be the "right of the citizen to be secure in his own home against the intrusion of poisons applied by other persons." Through ignorance, greed, and negligence, government had allowed "poisonous and biologically potent chemicals" to fall "indiscriminately into the hands of persons largely or wholly ignorant of their potentials for harm." When the public protested, it was "fed little tranquillizing pills of half-truth" by a government that refused to take responsibility for or acknowledge evidence of damage. Carson challenged such moral vacuity. "The obligation to endure," she wrote, "gives us the right to know."

In Carson's view, the postwar culture of science that arro-

gantly claimed dominion over nature was the philosophic root of the problem. Human beings, she insisted, were not in control of nature but simply one of its parts: the survival of one part depended upon the health of all. She protested the "contamination of man's total environment" with substances that accumulate in the tissues of plants, animals, and humans and have the potential to alter the genetic structure of organisms.

Carson argued that the human body was permeable and, as such, vulnerable to toxic substances in the environment. Levels of exposure could not be controlled, and scientists could not accurately predict the long-term effects of bioaccumulation in the cells or the impact of such a mixture of chemicals on human health. She categorically rejected the notion proposed by industry that there were human "thresholds" for such poisons, as well as its corollary, that the human body had "assimilative capacities" that rendered the poisons harmless. In one of the most controversial parts of her book, Carson presented evidence that some human cancers were linked to pesticide exposure. That evidence and its subsequent elaboration by many other researchers continue to fuel one of the most challenging and acrimonious debates within the scientific and environmental communities.

Carson's concept of the ecology of the human body was a major departure in our thinking about the relationship between humans and the natural environment. It had enormous consequences for our understanding of human health as well as our attitudes toward environmental risk. *Silent Spring* proved that our bodies are not boundaries. Chemical corruption of the globe affects us from conception to death. Like the rest of nature, we are vulnerable to pesticides; we too are permeable. All forms of life are more alike than different.

Carson believed that human health would ultimately reflect the environment's ills. Inevitably this idea has changed our response to nature, to science, and to the technologies that devise and deliver contamination. Although the scientific community

has been slow to acknowledge this aspect of Carson's work, her concept of the ecology of the human body may well prove to be one of her most lasting contributions.

In 1962, however, the multimillion-dollar industrial chemical industry was not about to allow a former government editor, a female scientist without a Ph.D. or an institutional affiliation, known only for her lyrical books on the sea, to undermine public confidence in its products or to question its integrity. It was clear to the industry that Rachel Carson was a hysterical woman whose alarming view of the future could be ignored or, if necessary, suppressed. She was a "bird and bunny lover," a woman who kept cats and was therefore clearly suspect. She was a romantic "spinster" who was simply overwrought about genetics. In short, Carson was a woman out of control. She had overstepped the bounds of her gender and her science. But just in case her claims did gain an audience, the industry spent a quarter of a million dollars to discredit her research and malign her character. In the end, the worst they could say was that she had told only one side of the story and had based her argument on unverifiable case studies.

There is another, private side to the controversy over *Silent Spring*. Unbeknown to her detractors in government and industry, Carson was fighting a far more powerful enemy than corporate outrage: a rapidly metastasizing breast cancer. The miracle is that she lived to complete the book at all, enduring a "catalogue of illnesses," as she called it. She was immune to the chemical industry's efforts to malign her; rather, her energies were focused on the challenge of survival in order to bear witness to the truth as she saw it. She intended to disturb and disrupt, and she did so with dignity and deliberation.

After *Silent Spring* caught the attention of President John F. Kennedy, federal and state investigations were launched into the validity of Carson's claims. Communities that had been subjected to aerial spraying of pesticides against their wishes began

to organize on a grass-roots level against the continuation of toxic pollution. Legislation was readied at all governmental levels to defend against a new kind of invisible fallout. The scientists who had claimed a "holy grail" of knowledge were forced to admit a vast ignorance. While Carson knew that one book could not alter the dynamic of the capitalist system, an environmental movement grew from her challenge, led by a public that demanded that science and government be held accountable. Carson remains an example of what one committed individual can do to change the direction of society. She was a revolutionary spokesperson for the rights of all life. She dared to speak out and confront the issue of the destruction of nature and to frame it as a debate over the quality of all life.

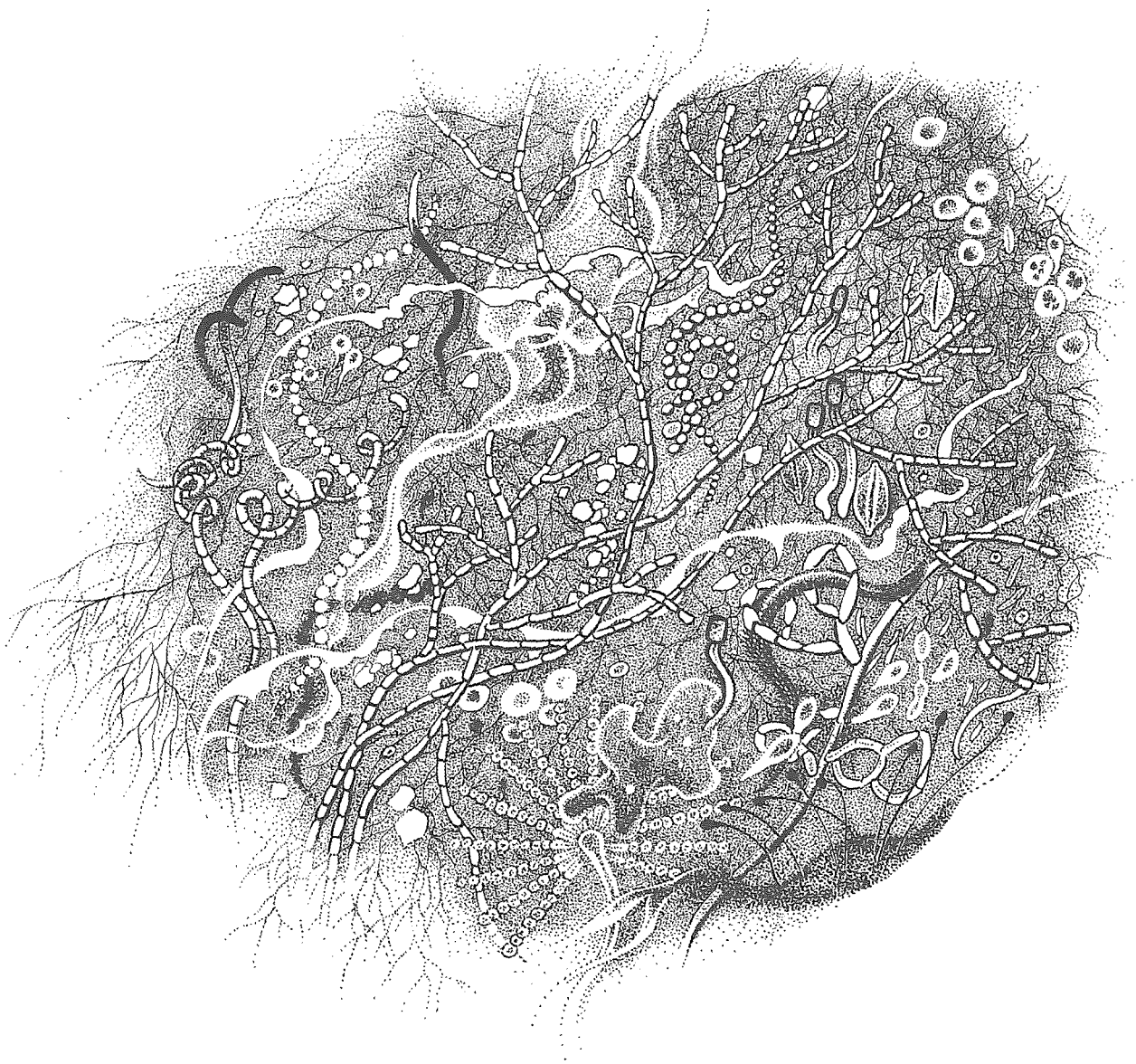
Rachel Carson knew before she died that her work had made a difference. She was honored by medals and awards, and posthumously received the Presidential Medal of Freedom in 1981. But she also knew that the issues she had raised would not be solved quickly or easily and that affluent societies are slow to sacrifice for the good of the whole. It was not until six years after Carson's death that concerned Americans celebrated the first Earth Day and that Congress passed the National Environmental Policy Act establishing the Environmental Protection Agency as a buffer against our own handiwork. The domestic production of DDT was banned, but not its export, ensuring that the pollution of the earth's atmosphere, oceans, streams, and wildlife would continue unabated. DDT is found in the livers of birds and fish on every oceanic island on the planet and in the breast milk of every mother. In spite of decades of environmental protest and awareness, and in spite of Rachel Carson's apocalyptic call alerting Americans to the problem of toxic chemicals, reduction of the use of pesticides has been one of the major policy failures of the environmental era. Global contamination is a fact of modern life.

Silent Spring compels each generation to reevaluate its rela-

tionship to the natural world. We are a nation still debating the questions it raised, still unresolved as to how to act for the common good, how to achieve environmental justice. In arguing that public health and the environment, human and natural, are inseparable, Rachel Carson insisted that the role of the expert had to be limited by democratic access and must include public debate about the risks of hazardous technologies. She knew then, as we have learned since, that scientific evidence by its very nature is incomplete and scientists will inevitably disagree on what constitutes certain proof of harm. It is difficult to make public policy in such cases when government's obligation to protect is mitigated by the nature of science itself.

Rachel Carson left us a legacy that not only embraces the future of life, in which she believed so fervently, but sustains the human spirit. She confronted us with the chemical corruption of the globe and called on us to regulate our appetites—a truly revolutionary stance—for our self-preservation. "It seems reasonable to believe," she wrote, "that the more clearly we can focus our attention on the wonders and realities of the universe about us, the less taste we shall have for the destruction of our race. Wonder and humility are wholesome emotions, and they do not exist side by side with a lust for destruction."

Wonder and humility are just some of the gifts of *Silent Spring*. They remind us that we, like all other living creatures, are part of the vast ecosystems of the earth, part of the whole stream of life. This is a book to relish: not for the dark side of human nature, but for the promise of life's possibility.



5. Realms of the Soil

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 animals could survive.

Yet if our agriculture-based life depends on the soil, it is equally true that soil depends on life, its very origins and the maintenance of its true nature being intimately related to living plants and animals. For soil is in part a creation of life, born of a marvelous interaction of life and nonlife long eons 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 their acid secretions and made a lodging place for other life. Mosses took hold in the 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.

Life not only formed the soil, but other living things of incredible abundance and diversity now exist within it; if this were not so the soil would be a dead and sterile thing. By their presence and by their activities the myriad organisms of the soil make it capable of supporting the earth's green mantle.

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. At the same time other materials are being taken away, borrowed for temporary 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 use by plants. In all these changes living organisms are active agents.

There are few studies more fascinating, and at the same time more neglected, than those of the teeming populations that exist in the dark realms of the soil. We know too little of the threads that bind the soil organisms to each other and 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 total weight of this host of bacteria in the top foot of a single acre of fertile soil may be as much as a thousand pounds. Ray fungi, growing in long threadlike filaments, are somewhat less numerous than the bacteria, yet because they are larger their total weight in a given amount of soil may be about the same. With small green cells called 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 minerals. 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 surrounded by a sea of nitrogen-containing air. Other organisms form carbon dioxide, which, as carbonic acid, aids in dissolving rock. Still other soil microbes perform various oxidations and reductions by which minerals such as iron, manganese, and sulfur are transformed and made available to plants.

Also present in prodigious numbers are microscopic mites and primitive wingless insects called springtails. Despite their small size they play an important part in breaking down the residues of plants, aiding 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 the fallen needles of a spruce tree. Sheltered here, they digest out the inner tissues of the needle. When 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 aid in mixing 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 are permanent residents of the dark subsurface layers; some hibernate or spend definite parts of their life cycles in underground chambers; some freely come and go between their burrows and the upper world. In general the effect of all this habitation of the soil is to aerate it and 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. 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 of earthworms as geologic agents for the transport of soil — a picture of surface rocks being gradually covered by fine soil brought up from below by the worms, in annual amounts running to many tons to the acre in most favorable areas. At the same time, quantities of organic matter contained in leaves and grass (as much as 20

pounds to the square yard in six months) are drawn down into the burrows and incorporated in soil. Darwin's calculations showed that the toil of earthworms might add a layer of soil an inch to an inch and a half thick in a ten-year period. And this is by no means all they do: their burrows aerate the soil, keep it well drained, and aid the penetration of plant roots. The presence of earthworms increases the nitrifying powers of the soil bacteria and decreases putrifaction of the soil. Organic matter is broken down as it passes through the digestive tracts of the worms and the soil is enriched by their excretory products.

This soil community, then, consists of a web of interwoven lives, each in some way related to the others — the living creatures depending on the soil, but the soil in turn a vital element of the earth only so long as this community within it flourishes.

The problem that concerns us here is one that has received little consideration: What happens to these incredibly numerous and vitally necessary inhabitants of the soil when poisonous chemicals are carried down into their world, either introduced directly as soil "sterilants" or borne on the rain that has picked up a lethal contamination as it filters through the leaf canopy of forest and orchard and cropland? Is it reasonable to suppose that we can apply a broad-spectrum insecticide to kill the burrowing larval stages of a crop-destroying insect, for example, without also killing the "good" insects whose function may be the essential one of breaking down organic matter? Or can we use a nonspecific fungicide without also killing the fungi that inhabit the roots of many trees in a beneficial association that aids 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. Chemical control of insects seems to have proceeded on the assumption that the soil could and would sustain any amount of insult via the

introduction of poisons without striking back. The very nature of the world of the soil has been largely ignored.

From the few studies that have been made, a picture of the impact of pesticides on the soil is slowly emerging. It is not surprising that the studies are not always in agreement, for soil types vary so enormously that what causes damage in one may be innocuous in another. Light sandy soils suffer far more heavily than humus types. Combinations of chemicals 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 many scientists.

Under some conditions, the chemical conversions and transformations that lie at the very heart of the living world are affected. Nitrification, which makes atmospheric nitrogen available to plants, is an example. The herbicide 2,4-D causes a temporary interruption of nitrification. In recent experiments in Florida, lindane, heptachlor, and BHC (benzene hexachloride) reduced nitrification after only two weeks in soil; BHC and DDT had significantly detrimental effects a year after treatment. In other experiments BHC, aldrin, lindane, heptachlor, and DDD all prevented nitrogen-fixing bacteria from forming the necessary root nodules on leguminous plants. A curious but beneficial relation between fungi and the roots of higher plants is seriously disrupted.

Sometimes the problem is one of upsetting that delicate balance of populations by which nature accomplishes far-reaching aims. Explosive increases in some kinds of soil organisms have occurred when others 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, could escape from their natural controls and rise to pest status.

One of the most important things to remember about in-

secticides in soil is their long persistence, measured not in months but in years. Aldrin has been recovered after four years, both as traces and more abundantly as converted to dieldrin. Enough toxaphene remains in sandy soil ten years after its application to kill termites. Benzene hexachloride persists at least eleven years; heptachlor or a more toxic derived chemical, at least nine. Chlordane has been recovered twelve years after its application, in the amount of 15 per cent of the original quantity.

Seemingly moderate applications of insecticides over a period of years may build up fantastic quantities in soil. Since the chlorinated hydrocarbons are persistent and long-lasting, each application is merely added to the quantity remaining from the previous one. The old 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 15 pounds of DDT per acre, corn soils up to 19. A cranberry bog under study contained 34.5 pounds to the acre. Soils from apple orchards seem to reach the peak of contamination, with DDT accumulating at a rate that almost keeps pace with its rate of annual application. Even in a single season, with orchards sprayed four or more times, DDT residues may build up to peaks of 30 to 50 pounds. With repeated spraying over the years the range between trees is from 26 to 60 pounds to the acre; under trees, up to 113 pounds.

Arsenic provides a classic case of the virtually permanent poisoning of the soil. Although arsenic as a spray on growing tobacco has been largely replaced by the synthetic organic insecticides since the mid-'40's, *the arsenic content of cigarettes made from American-grown tobacco increased more than 300 per cent* between the years 1932 and 1952. Later studies have revealed increases of as much as 600 per cent. Dr. Henry S. Satterlee, an authority on arsenic toxicology, says that although organic insecticides have been largely substituted for arsenic, the tobacco plants continue to pick up the old poison, for the soils

of tobacco plantations are now thoroughly impregnated with residues of a heavy and relatively insoluble poison, arsenate of lead. This will continue to release arsenic in soluble form. The soil of a large proportion of the land planted to tobacco has been subjected to "cumulative and well-nigh permanent poisoning," according to Dr. Satterlee. Tobacco grown in the eastern Mediterranean countries where arsenical insecticides are not used has shown no such increase in arsenic content.

We are therefore confronted with a second problem. We must not only be concerned with what is happening to the soil; we must wonder to what extent insecticides are absorbed from contaminated soils and introduced into plant tissues. Much depends on the type of soil, the crop, and the nature and concentration of the insecticide. Soil high in organic matter releases smaller quantities of poisons than others. Carrots absorb more insecticide than any other crop studied; if the chemical 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 even unsprayed crops may take up enough insecticide merely from the soil to render them unfit for market.

This very sort of contamination has created endless problems for at least one leading manufacturer of baby foods who has been unwilling to buy any fruits or vegetables on which toxic insecticides have been used. The chemical that caused him the most trouble was benzene hexachloride (BHC), which is taken up by the roots and tubers of plants, advertising its presence by a musty taste and odor. Sweet potatoes grown on California fields where BHC had been used two years earlier contained residues and had to be rejected. In one year, in which the firm had contracted in South Carolina for its total requirements of sweet potatoes, 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. Over the years a variety of fruits and vegetables, grown in various states, have had to be rejected. The most stubborn problems were concerned with peanuts. In the southern states peanuts are usually grown in rotation with cotton, on which BHC is extensively used. Peanuts grown later in this soil pick up considerable amounts of the insecticide. Actually, only a trace is enough to incorporate the telltale musty odor and taste. The chemical penetrates the nuts and cannot be removed. Processing, far from removing the mustiness, sometimes accentuates it. The only course open to a manufacturer determined to exclude BHC residues is to reject all produce treated with the chemical or grown on soils contaminated with it.

Sometimes the menace is to the crop itself — a menace that remains as long as the insecticide contamination is in the soil. Some insecticides affect sensitive plants such as beans, wheat, barley, or rye, retarding root development or depressing growth of seedlings. The experience of the hop growers in 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 as the control agent. Within a year after the heptachlor was applied, the vines in the treated yards were wilting and dying. In the untreated fields there was no trouble; the damage stopped at the border between treated and untreated fields. The hills were replanted at great expense, but in another 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 federal Department of Agriculture, which as late as March 1959 found itself in the anomalous position of declaring heptachlor to be acceptable for use

on hops in the form of a soil treatment, belatedly withdrew its registration for such use. Meanwhile, the hop growers sought what redress they could in the courts.

As applications of pesticides continue and the virtually indestructible residues continue to build up in the soil, it is almost certain that we are heading for trouble. This was the consensus of a group of specialists who met at Syracuse University in 1960 to discuss the ecology of the soil. These men summed up the hazards of using "such potent and little understood tools" as chemicals and radiation: "A few false moves on the part of man may result in destruction of soil productivity and the arthropods may well take over."

Afterword

by Edward O. Wilson

When it appeared in 1962, *Silent Spring* delivered a galvanic jolt to public consciousness and, as a result, infused the environmental movement with new substance and meaning. The effects of pesticides and other toxic chemical pollutants on the environment and public health had been well documented before *Silent Spring,* but in bits and pieces scattered through the technical literature. Environmental scientists were aware of the problem, but by and large they focused only on the narrow sector of their personal expertise. It was Rachel Carson's achievement to synthesize this knowledge into a single image that everyone, scientists and the general public alike, could easily understand.

The need for such a book was great even within the sciences. As the mild-mannered aquatic biologist was researching *Silent Spring,* ecology was near the bottom of the scientific disciplines in prestige and support; few Americans even knew what the world meant. Conservation biology, later to become one of the most rapidly growing disciplines, did not exist. At the time, the scientific culture was fixated on the spectacular success of the molecular revolution, which had placed physics and chemistry at the foundation of biology. Researchers were learning to reduce living processes to their molecular elements. I, for example, as a young naturalist trained in field biology, was busy collaborating with organic chemists to break the code of pheromones used by ants to organize their colonies.

The environment was also excluded from the mainstream political agenda. America in the late 1950s and early 1960s was an exuberant and prospering nation. Buoyed by record peacetime

economic growth, an ethic of limitless progress prevailed, yet the country, locked in a cold war that threatened our way of life, was vulnerable to the formidable enemies that encircled us. The Soviet Union had matched the United States in nuclear weaponry and beaten us into space, and on the Asian mainland China held us at a military standstill. For the sake of our prosperity and security, we rewarded science and technology with high esteem and placed great trust in the seeming infallibility of material ingenuity. As a consequence, environmental warnings were treated with irritable impatience. To a populace whose forebears had within living memory colonized the interior of a vast continent and whose country had never lost a war, arguments for limit and constraint seemed almost unpatriotic.

The temper of the times was epitomized by the concept of the peaceful use of atoms, which culminated in federal plans to excavate harbors and waterways with low-yield nuclear explosions. One such proposal seriously considered by engineers was the instant construction of a sea-level channel parallel to the Panama Canal with a string of precisely timed detonations. Fortunately, that particular dream never left the drawing board. Aside from the foreign policy complications inherent in cutting a Central American country into two pieces, there was a biological risk. The U.S. National Research Council committee reviewing the plan (on which I served as a junior member) raised a warning hand. We pointed out that organisms living in the shallow waters of the eastern Pacific are very different from those in the Caribbean. The two faunas, having evolved independently of each other for millions of years while separated by the intervening Panamanian isthmus, would now be mingled by currents flooding from the Pacific side. Among the many unfortunate likely results would be the invasion of the Caribbean waters by poisonous sea snakes as well as by sea wasps, a form of stinging jellyfish.

A second example of national impetuosity I happened to wit-

ness was the U.S. Department of Agriculture's fire ant eradication program. Rachel Carson was to label it, in *Silent Spring,* "an outstanding example of an ill-conceived, badly executed, and thoroughly detrimental experiment in the mass control of insects, an experiment so expensive in dollars, in destruction of animal life, and in loss of public confidence in the Agriculture Department that it is incomprehensible that any funds should still be devoted to it."

The target of this fiasco was the red imported fire ant *(Solenopsis invicta),* which had been introduced into the port of Mobile, Alabama, most likely in cargo shipped from Argentina. Its colonies, each containing several hundred thousand very aggressive workers, construct soil nests surmounted by mounds as much as a foot high. The name fire ant comes from its sting, which feels like a burning match held too close to the skin. The exact time of the establishment of the species in the United States is not known, but was probably sometime in the 1930s. By rare coincidence I was the first person unofficially to record its presence. In 1942, as a thirteen-year-old Boy Scout studying ant species around my home near the Mobile docks, I discovered a single well-developed colony of red imported fire ants. Seven years later, when the species had become abundant enough to rank as a local pest, I was hired by the state of Alabama to make the first thorough study of its habits and distribution. I found that the ants were spreading radially outward from Mobile at the rate of about five miles a year and had already reached the borders of Florida and Mississippi. By continuing this advance, and also by hitchhiking in nursery and farm products, they were destined to spread during the next several decades throughout the South from the Carolinas to Texas.

The red imported fire ant was and remains a serious nuisance. Its stings are unpleasant, and on rare occasions the venom triggers fatal anaphylactic shock. The teeming workers have been known to attack seedling corn and other crops as well as the

hatchlings of ground-nesting birds. Its mounds are large and numerous enough to interfere with the operation of farm machinery. Yet it was never an economic pest in the same class as the boll weevil, gypsy moth, European corn borer, and other destructive insects.

Its conspicuous and menacing behavior nevertheless caused enough alarm for the U.S. Department of Agriculture, with enthusiastic support from the pesticide industry, to launch an eradication effort, not just to control the ant but to remove it entirely from American soil. In 1958 a million acres were sprayed with the powerful insecticides dieldrin and heptachlor. As Rachel Carson documented in *Silent Spring,* the environmental results were catastrophic. Wildlife and livestock exposed to the poisons, through direct contact or in polluted water, began to suffer an often fatal nervous disorder. Many bird populations were decimated. The effects on human health were never assessed, and the probably destructive elements on native insect populations—those elements necessary for the healthy functioning of the natural ecosystems—were hardly mentioned.

The red imported fire ants bounded back after the pesticide carpet bombing and continued their spread across the South without pause. This disconcerting outcome was easy to predict. In the genetic strain of the red imported fire ant then prevalent, each colony is started by a single mated queen and grows to maturity within one to three years. At that point it starts to generate thousands of new queens, each capable of traveling for miles in the air before settling down to start a new colony. Just one surviving colony missed by the poison sprays is enough to reseed an area of many square miles. When a new formal scientific name was later picked for the species (to clear up a confusion in its taxonomic history), the logical choice was *invicta,* meaning "unconquered." By the late 1960s, as the eradication effort wound down, I felt justified in calling the campaign against the unconquered ant the "Vietnam of Entomology."

Rachel Carson, in recounting such horror stories in *Silent Spring,* did not call for an end to pest control. Rather, she asked for an end to reckless endangerment by the use of broad-spectrum pesticides. These substances, she argued, should never be spread across the nation's fruited plains without adequate and public knowledge of their impact on the environment and human health. Instead, she insisted, we must switch to clean, precise solutions based on science and broad environmental knowledge.

For the most part, Americans listened and began to turn away from wholesale toxic pollution. The Carson ethic spread to other countries and to other venues within each country. It is not possible exactly to assess the full influence of *Silent Spring* on American environmentalism. In the decades that followed, the book's message was blended with other scientific and literary efforts and folded into the growing activist movement, which was drawn from multiple social and political agendas. But whatever the genealogy, no one can deny that Rachel Carson's book exerted, and continues to exert, a major influence. In immediate impact, it accelerated the resistance to chemical pollution that is all but universal today—in word if not always in deed. *Silent Spring* also became a national political force, largely responsible for the establishment of the Environmental Protection Agency in 1970. The task of pesticide oversight and the Food Safety Inspection Service were transferred to the new agency from the Department of Agriculture, marking a turnabout in policy emphasis from the benefits of chemical crop treatments to their risks.

A collateral effect of *Silent Spring* was the boost it gave to conservation of natural environments. Chemical pollution is the third-ranking cause of species extinction in the United States, after habitat destruction and "biological pollution"—the influx of alien species that outcompete and push back native ones. The general environmental concern abetted by *Silent Spring* resulted

in the passage in 1973 of the Endangered Species Act by a near-unanimous vote in Congress. The act is easily the most important piece of conservation legislation in the nation's history. Its most dramatic successes include the recovery of the American alligator, gray whale, bald eagle, peregrine falcon, and eastern population of the brown pelican. All were imperiled when her book first appeared, and all are now considered relatively safe.

The environmental movement nevertheless is still forced to work its way up the rough side of the mountain, even in the country that gave it birth. If Rachel Carson were alive today, I believe she would give America a mixed grade. The increased public awareness of the environment would please the educator in her; the ranking of her book as a literary classic would astonish the writer; and the existence of new regulatory laws would gratify the frustrated government bureaucrat. The naturalist in Rachel Carson, positioned at the core of her several parts, would take pleasure in knowing that ecocidal schemes such as the sea-level canal and the fire ant eradication program, if broached today, would be widely ridiculed and perish stillborn.

Even so, she would recognize that the war between environ mentalists and exploiters, local and national, is far from over. It has only subsided since 1962 to a more muted equilibrium. Although developers and policymakers come up with fewer spectacularly bad large projects, they continue to chip, saw, and drill away at the remains of the American natural environment. They say, over and over, we just need a little more here and there. The environmentalists respond by saying, pull back: nature is dying the torture-death of a thousand cuts.

Of the 1,254 species protected under the Endangered Species Act at the end of 1991, four times as many are declining as are gaining in population. The enemies of federal environmental regulation cite this difference as evidence that the act has failed. Their logic, if applied widely, would call for closing hospital emergency rooms because so many people die there. They declare the Endangered Species Act a detriment to economic

growth, conveniently ignoring the fact that fewer than one in a thousand projects reviewed under its provisions has been halted.

Since *Silent Spring's* publication the United States has come to understand that it is a major player in the deterioration of the global environment. Rachel Carson, who was a quick learner, would be ahead of us in understanding the devastating effects everywhere of still-rocketing population growth combined with consumption of natural resources, the thinning of the ozone layer, global warming, the collapse of marine fisheries, and, less directly through foreign trade, the decimation of tropical forests and mass extinction of species. She would regret, I am sure, the sorry example the United States sets with its enormous per capita appropriation of productive land around the world for its consumption — ten times that of developing countries.

On the other hand, the lady from Maryland would take some hope from Earth Summit, the successful Montreal Protocol aimed at the reduction of ozone-thinning chlorofluorocarbons, and the less successful Kyoto Protocol designed to slow climatic warming (still thwarted by lack of American approval). She would be cheered by news of the rapid growth in funding by the muscle of such global nongovernmental organizations as Conservation International, the Nature Conservancy, and the World Wildlife Fund–U.S.

Silent Spring continues to be worthy of our attention because it marks an important moment in history, just as Harriet Beecher Stowe's *Uncle Tom's Cabin* and John Muir's *Our National Parks* do. The examples and arguments it contains are timeless lessons of the kind we need to reexamine. They are also timely, because the battle Rachel Carson helped to lead on behalf of the environment is far from won.

We are still poisoning the air and water and eroding the biosphere, albeit less so than if Rachel Carson had not written. Today we understand better than ever why we must press the effort to save the environment all the way home, true to the mind and spirit of the valiant author of *Silent Spring.*