BY RACHEL CARSON

Under the Sea-Wind

The Sea Around Us

The Edge of the Sea

Silent Spring

SILENT SPRING

FORTIETH ANNIVERSARY EDITION

RACHEL CARSON

Introduction by Linda Lear

Afterword by Edward O. Wilson

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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 arrogantly 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.


I. A Fable for Tomorrow

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

Along the roads, laurel, viburnum and alder, great ferns and wildflowers delighted the traveler'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 traveled from great distances to observe them. Others came to fish the streams, which flowed clear and cold out of the hills and contained shady pools where trout lay. So it had been from the days many years ago when the first settlers raised their houses, sank their wells, and built their barns.

Then a strange blight crept over the area and everything began to change. Some evil spell had settled on the community: mysterious maladies swept the flocks of chickens; the cattle and sheep sickened and died. Everywhere was a shadow of death. The farmers spoke of much illness among their families. In the town the doctors had become more and more puzzled by new kinds of sickness appearing among their patients. There had been several sudden and unexplained deaths, not only among adults but even among children, who would be stricken suddenly while at play and die within a few hours.

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

On the farms the hens brooded, but no chicks hatched. The farmers complained that they were unable to raise any pigs — the litters were small and the young survived only a few days. The apple trees were coming into bloom but no bees droned

among the blossoms, so there was no pollination and there would be no fruit.

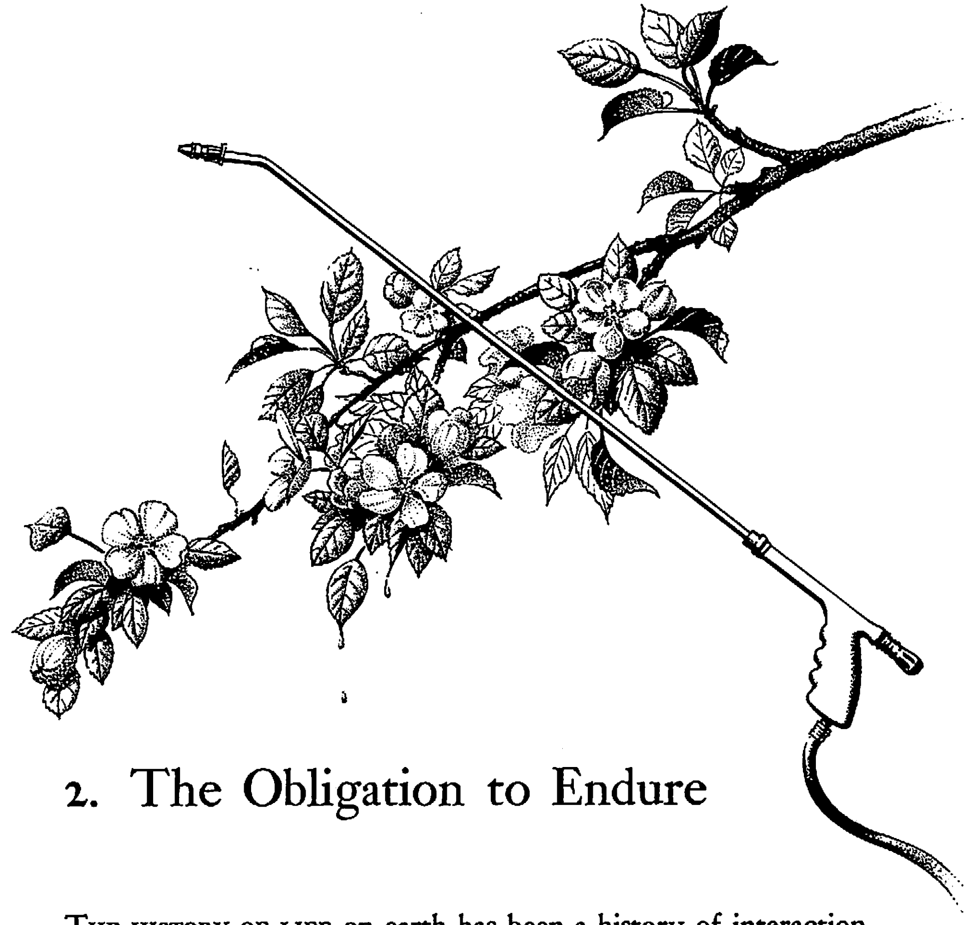
The roadsides, once so attractive, were now lined with browned and withered vegetation as though swept by fire. These, too, were silent, deserted by all living things. Even the streams were now lifeless. Anglers no longer visited them, for all the fish had died.

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

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

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

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



2. The Obligation to Endure

THE HISTORY OF LIFE on earth has been a history of interaction between living things and their surroundings. To a large extent, the physical form and the habits of the earth's vegetation and its animal life have been molded by the environment. Considering the whole span of earthly time, the opposite effect, in which life actually modifies its surroundings, has been relatively slight. Only within the moment of time represented by the present century has one species — man — acquired significant power to alter the nature of his world.

During the past quarter century this power has not only increased to one of disturbing magnitude but it has changed in character. The most alarming of all man's assaults upon the environment is the contamination of air, earth, rivers, and sea with dangerous and even lethal materials. This pollution 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. In this now universal contamination of the environment, chemicals are the sinister and little-recognized partners of radiation in changing the very nature of the world — the very nature of its life. Strontium 90, released through nuclear explosions into the air, 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. Similarly, chemicals sprayed on croplands or forests or gardens lie long in soil, entering into living organisms, passing from one to another in a chain of poisoning and death. Or they pass mysteriously by underground streams until they emerge and, through the alchemy of air and sunlight, combine into new forms that 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 — eons of time in which that developing and evolving and diversifying life reached a state of adjustment and balance with its surroundings. The environment, rigorously shaping and directing the life it supported, contained elements that were hostile as well as supporting. 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. Given time — time not in years but in millennia — life adjusts, and a balance has been reached. For time is the essential ingredient; but in the modern world there is no time.

The rapidity of change and the speed with which new situations are created follow 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 that have existed before there was any life on earth; radiation is now 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 all the rest of the minerals washed out of the rocks and carried in rivers to the sea; they are 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, were it by some miracle possible, would be futile, for the new chemicals come from our laboratories 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 — 500 new chemicals to which the bodies of men and animals are required somehow to adapt each year, chemicals totally outside the limits of biologic experience.

Among them are many that are used in man's war against nature. Since the mid-1940's over 200 basic chemicals have been created for use in killing insects, weeds, rodents, and other organisms described in the modern vernacular as "pests"; and they are sold under several thousand different brand names.

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

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

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

Some would-be architects of our future look toward a time when it will be possible to alter the human germ plasm by design. But we may easily be doing so now by inadvertence, for many chemicals, like radiation, bring about gene mutations. It is ironic to think that man might determine his own future by something so seemingly trivial as the choice of an insect spray.

All this has been risked — for what? Future historians may well be amazed by our distorted sense of proportion. How could intelligent beings seek to control a few unwanted species by a method that contaminated the entire environment and brought the threat of disease and death even to their own kind?

Yet this is precisely what we have done. We have done it, moreover, for reasons that collapse the moment we examine them. We are told that the enormous and expanding use of pesticides is necessary to maintain farm production. Yet is our real problem not one of *overproduction?* Our farms, despite measures to remove acreages from production and to pay farmers *not* to produce, have yielded such a staggering excess of crops that the American taxpayer in 1962 is paying out more than one billion dollars a year as the total carrying cost of the surplus-food storage program. And is the situation helped when one branch of the Agriculture Department tries to reduce production while another states, as it did in 1958, "It is believed generally that reduction of crop acreages under provisions of the Soil Bank will stimulate interest in use of chemicals to obtain maximum production on the land retained in crops."

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

The problem whose attempted solution has brought such a train of disaster in its wake is an accompaniment of our modern way of life. Long before the age of man, insects inhabited the earth — a group of extraordinarily varied and adaptable beings. Over the course of time since man's advent, a small percentage of the more than half a million species of insects have come into conflict with human welfare in two principal ways: as competitors for the food supply and as carriers of human disease.

Disease-carrying insects become important where human beings are crowded together, especially under conditions where sanitation is poor, as in time of natural disaster or war or in situations of extreme poverty and deprivation. Then control of some sort becomes necessary. It is a sobering fact, however, Louisiana State University Agricultural Experiment Station, Dr. L. D. Newsom: "The imported fire ant 'eradication' program which has been conducted by state and federal agencies is thus far a failure. There are more infested acres in Louisiana now than when the program began."

A swing to more sane and conservative methods seems to have begun. Florida, reporting that "there are more fire ants in Florida now than there were when the program started," announced it was abandoning any idea of a broad eradication program and would instead concentrate on local control.

Effective and inexpensive methods of local control have been known for years. The mound-building habit of the fire ant makes the chemical treatment of individual mounds a simple matter. Cost of such treatment is about one dollar per acre. For situations where mounds are numerous and mechanized methods are desirable, a cultivator which first levels and then applies chemical directly to the mounds has been developed by Mississippi's Agricultural Experiment Station. The method gives 90 to 95 per cent control of the ants. Its cost is only $.23 per acre. The Agriculture Department's mass control program, on the other hand, cost about $3.50 per acre — the most expensive, the most damaging, and the least effective program of all.

11. Beyond the Dreams of the Borgias

THE CONTAMINATION of our world is not alone a matter of mass spraying. Indeed, for most of us this is of less importance than the innumerable small-scale exposures to which we are subjected day by day, year after year. Like the constant dripping of water that in turn wears away the hardest stone, this birth-to-death contact with dangerous chemicals may in the end prove disastrous. Each of these recurrent exposures, no matter how slight, contributes to the progressive buildup of chemicals in our bodies and so to cumulative poisoning. Probably no person is immune to contact with this spreading contamination unless he lives in the most isolated situation imaginable. Lulled by the soft sell and the hidden persuader, the average citizen is seldom aware of the deadly materials with which he is surrounding himself; indeed, he may not realize he is using them at all.

So thoroughly has the age of poisons become established that anyone may walk into a store and, without questions being asked, buy substances of far greater death-dealing power than the medicinal drug for which he may be required to sign a "poison book" in the pharmacy next door. A few minutes' research in any supermarket is enough to alarm the most stouthearted customer — provided, that is, he has even a rudimentary knowledge of the chemicals presented for his choice.

If a huge skull and crossbones were suspended above the insecticide department the customer might at least enter it with the respect normally accorded death-dealing materials. But instead the display is homey and cheerful, and, with the pickles and olives across the aisle and the bath and laundry soaps adjoining, the rows upon rows of insecticides are displayed. Within easy reach of a child's exploring hand are chemicals in *glass* containers. If dropped to the floor by a child or careless adult everyone nearby could be splashed with the same chemical that has sent spraymen using it into convulsions. These hazards of course follow the purchaser right into his home. A can of a mothproofing material containing DDD, for example, carries in very fine print the warning that its contents are under pressure and that it may burst if exposed to heat or open flame. A common insecticide for household use, including assorted uses in the kitchen, is chlordane. Yet the Food and Drug Administration's chief pharmacologist has declared the hazard of living in a house sprayed with chlordane to be "very great." Other household preparations contain the even more toxic dieldrin.

Use of poisons in the kitchen is made both attractive and easy. Kitchen shelf paper, white or tinted to match one's color scheme,

may be impregnated with insecticide, not merely on one but on both sides. Manufacturers offer us do-it-yourself booklets on how to kill bugs. With push-button ease, one may send a fog of dieldrin into the most inaccessible nooks and crannies of cabinets, corners, and baseboards.

If we are troubled by mosquitoes, chiggers, or other insect pests on our persons we have a choice of innumerable lotions, creams, and sprays for application to clothing or skin. Although we are warned that some of these will dissolve varnish, paint, and synthetic fabrics, we are presumably to infer that the human skin is impervious to chemicals. To make certain that we shall at all times be prepared to repel insects, an exclusive New York store advertises a pocket-sized insecticide dispenser, suitable for the purse or for beach, golf, or fishing gear.

We can polish our floors with a wax guaranteed to kill any insect that walks over it. We can hang strips impregnated with the chemical lindane in our closets and garment bags or place them in our bureau drawers for a half year's freedom from worry over moth damage. The advertisements contain no suggestion that lindane is dangerous. Neither do the ads for an electronic device that dispenses lindane fumes — we are told that it is safe and odorless. Yet the truth of the matter is that the American Medical Association considers lindane vaporizers so dangerous that it conducted an extended campaign against them in its *Journal*.

The Department of Agriculture, in a *Home and Garden Bulletin,* advises us to spray our clothing with oil solutions of DDT, dieldrin, chlordane, or any of several other moth killers. If excessive spraying results in a white deposit of insecticide on the fabric, this may be removed by brushing, the Department says, omitting to caution us to be careful where and how the brushing is done. All these matters attended to, we may round out our day with insecticides by going to sleep under a mothproof blanket impregnated with dieldrin.

Gardening is now firmly linked with the super poisons. Every hardware store, garden-supply shop, and supermarket has rows of insecticides for every conceivable horticultural situation. Those who fail to make wide use of this array of lethal sprays and dusts are by implication remiss, for almost every newspaper's garden page and the majority of the gardening magazines take their use for granted.

So extensively are even the rapidly lethal organic phosphorus insecticides applied to lawns and ornamental plants that in 1960 the Florida State Board of Health found it necessary to forbid the commercial use of pesticides in residential areas by anyone who had not first obtained a permit and met certain requirements. A number of deaths from parathion had occurred in Florida before this regulation was adopted.

Little is done, however, to warn the gardener or homeowner that he is handling extremely dangerous materials. On the contrary, a constant stream of new gadgets make it easier to use poisons on lawn and garden — and increase the gardener's contact with them. One may get a jar-type attachment for the garden hose, for example, by which such extremely dangerous chemicals as chlordane or dieldrin are applied as one waters the lawn. Such a device is not only a hazard to the person using the hose; it is also a public menace. The *New York Times* found it necessary to issue a warning on its garden page to the effect that unless special protective devices were installed poisons might get into the water supply by back siphonage. Considering the number of such devices that are in use, and the scarcity of warnings such as this, do we need to wonder why our public waters are contaminated?

As an example of what may happen to the gardener himself, we might look at the case of a physician — an enthusiastic sparetime gardener — who began using DDT and then malathion on his shrubs and lawn, making regular weekly applications. Sometimes he applied the chemicals with a hand spray, sometimes

with an attachment to his hose. In doing so, his skin and clothing were often soaked with spray. After about a year of this sort of thing, he suddenly collapsed and was hospitalized. Examination of a biopsy specimen of fat showed an accumulation of 23 parts per million of DDT. There was extensive nerve damage, which his physicians regarded as permanent. As time went on he lost weight, suffered extreme fatigue, and experienced a peculiar muscular weakness, a characteristic effect of malathion. All of these persisting effects were severe enough to make it difficult for the physician to carry on his practice.

Besides the once innocuous garden hose, power mowers also have been fitted with devices for the dissemination of pesticides, attachments that will dispense a cloud of vapor as the homeowner goes about the task of mowing his lawn. So to the potentially dangerous fumes from gasoline are added the finely divided particles of whatever insecticide the probably unsuspecting suburbanite has chosen to distribute, raising the level of air pollution above his own grounds to something few cities could equal.

Yet little is said about the hazards of the fad of gardening by poisons, or of insecticides used in the home; warnings on labels are printed so inconspicuously in small type that few take the trouble to read or follow them. An industrial firm recently undertook to find out just *how* few. Its survey indicated that fewer than fifteen people out of a hundred of those using insecticide aerosols and sprays are even aware of the warnings on the containers.

The mores of suburbia now dictate that crabgrass must go at whatever cost. Sacks containing chemicals designed to rid the lawn of such despised vegetation have become almost a status symbol. These weed-killing chemicals are sold under brand names that never suggest their identity or nature. To learn that they contain chlordane or dieldrin one must read exceedingly fine print placed on the least conspicuous part of the sack. The descriptive literature that may be picked up in any hardware- or garden-supply store seldom if ever reveals the true hazard involved in handling or applying the material. Instead, the typical illustration portrays a happy family scene, father and son smilingly preparing to apply the chemical to the lawn, small children tumbling over the grass with a dog.

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

It has been medically established that, as common sense would tell us, persons who lived and died before the dawn of the DDT era (about 1942) contained no trace of DDT or any similar material in their tissues. As mentioned in Chapter 3, samples of body fat collected from the general population between 1954 and 1956 averaged from 5.3 to 7.4 parts per million of DDT. There is some evidence that the average level has risen since then to a consistently higher figure, and individuals with occupational or other special exposures to insecticides of course store even more.

Among the general population with no known gross exposures to insecticides it may be assumed that much of the DDT stored in fat deposits has entered the body in food. To test this assumption, a scientific team from the United States Public Health Service sampled restaurant and institutional meals. *Every meal sampled contained DDT*. From this the investigators concluded, reasonably enough, that "few if any foods can be relied upon to be entirely free of DDT."

The quantities in such meals may be enormous. In a separate Public Health Service study, analysis of prison meals disclosed

such items as stewed dried fruit containing 69.6 parts per million and bread containing 100.9 parts per million of DDT!

In the diet of the average home, meats and any products derived from animal fats contain the heaviest residues of chlorinated hydrocarbons. This is because these chemicals are soluble in fat. Residues on fruits and vegetables tend to be somewhat less. These are little affected by washing — the only remedy is to remove and discard all outside leaves of such vegetables as lettuce or cabbage, to peel fruit and to use no skins or outer covering whatever. Cooking does not destroy residues.

Milk is one of the few foods in which no pesticide residues are permitted by Food and Drug Administration regulations. In actual fact, however, residues turn up whenever a check is made. They are heaviest in butter and other manufactured dairy products. A check of 461 samples of such products in 1960 showed that a third contained residues, a situation which the Food and Drug Administration characterized as "far from encouraging."

To find a diet free from DDT and related chemicals, it seems one must go to a remote and primitive land, still lacking the amenities of civilization. Such a land appears to exist, at least marginally, on the far Arctic shores of Alaska — although even there one may see the approaching shadow. When scientists investigated the native diet of the Eskimos in this region it was found to be free from insecticides. The fresh and dried fish; the fat, oil, or meat from beaver, beluga, caribou, moose, oogruk, polar bear, and walrus; cranberries, salmonberries and wild rhubarb all had so far escaped contamination. There was only one exception — two white owls from Point Hope carried small amounts of DDT, perhaps acquired in the course of some migratory journey.

When some of the Eskimos themselves were checked by analysis of fat samples, small residues of DDT were found (0 to 1.9 parts per million). The reason for this was clear. The fat samples were taken from people who had left their native villages to enter the United States Public Health Service Hospital in Anchorage for surgery. There the ways of civilization prevailed, and the meals in this hospital were found to contain as much DDT as those in the most populous city. For their brief stay in civilization the Eskimos were rewarded with a taint of poison.

The fact that every meal we eat carries its load of chlorinated hydrocarbons is the inevitable consequence of the almost universal spraying or dusting of agricultural crops with these poisons. If the farmer scrupulously follows the instructions on the labels, his use of agricultural chemicals will produce no residues larger than are permitted by the Food and Drug Administration. Leaving aside for the moment the question whether these legal residues are as "safe" as they are represented to be, there remains the well-known fact that farmers very frequently exceed the prescribed dosages, use the chemical too close to the time of harvest, use several insecticides where one would do, and in other ways display the common human failure to read the fine print.

Even the chemical industry recognizes the frequent misuse of insecticides and the need for education of farmers. One of its leading trade journals recently declared that "many users do not seem to understand that they may exceed insecticide tolerances if they use higher dosages than recommended. And haphazard use of insecticides on many crops may be based on farmers' whims."

The files of the Food and Drug Administration contain records of a disturbing number of such violations. A few examples will serve to illustrate the disregard of directions: a lettuce farmer who applied not one but eight different insecticides to his crop within a short time of harvest, a shipper who had used the deadly parathion on celery in an amount five times the recommended maximum, growers using endrin — most toxic of all the chlorinated hydrocarbons — on lettuce although no residue was allowable, spinach sprayed with DDT a week before harvest.

There are also cases of chance or accidental contamination. Large lots of green coffee in burlap bags have become contaminated while being transported by vessels also carrying a cargo of insecticides. Packaged foods in warehouses are subjected to repeated aerosol treatments with DDT, lindane, and other insecticides, which may penetrate the packaging materials and occur in measurable quantities on the contained foods. The longer the food remains in storage, the greater the danger of contamination.

To the question "But doesn't the government protect us from such things?" the answer is, "Only to a limited extent." The activities of the Food and Drug Administration in the field of consumer protection against pesticides are severely limited by two facts. The first is that it has jurisdiction only over foods shipped in interstate commerce; foods grown and marketed within a state are entirely outside its sphere of authority, no matter what the violation. The second and critically limiting fact is the small number of inspectors on its staff — fewer than 600 men for all its varied work. According to a Food and Drug official, only an infinitesimal part of the crop products moving in interstate commerce — far less than 1 per cent — can be checked with existing facilities, and this is not enough to have statistical significance. As for food produced and sold within a state, the situation is even worse, for most states have woefully inadequate laws in this field.

The system by which the Food and Drug Administration establishes maximum permissible limits of contamination, called "tolerances," has obvious defects. Under the conditions prevailing it provides mere paper security and promotes a completely unjustified impression that safe limits have been established and are being adhered to. As to the safety of allowing a sprinkling of poisons on our food — a little on this, a little on that — many people contend, with highly persuasive reasons, that no poison is safe or desirable on food. In setting a tolerance level the Food and Drug Administration reviews tests of the poison on laboratory animals and then establishes a maximum level of contamination that is much less than required to produce symptoms in the test animal. This system, which is supposed to ensure safety, ignores a number of important facts. A laboratory animal, living under controlled and highly artificial conditions, consuming a given amount of a specific chemical, is very different from a human being whose exposures to pesticides are not only multiple but for the most part unknown, unmeasurable, and uncontrollable. Even if 7 parts per million of DDT on the lettuce in his luncheon salad were "safe," the meal includes other foods, each with allowable residues, and the pesticides on his food are, as we have seen, only a part, and possibly a small part, of his total exposure. This piling up of chemicals from many different sources creates a total exposure that cannot be measured. It is meaningless, therefore, to talk about the "safety" of any specific amount of residue.

And there are other defects. Tolerances have sometimes been established against the better judgment of Food and Drug Administration scientists, as in the case cited on page 224 ff., or they have been established on the basis of inadequate knowledge of the chemical concerned. Better information has led to later reduction or withdrawal of the tolerance, but only after the public has been exposed to admittedly dangerous levels of the chemical for months or years. This happened when heptachlor was given a tolerance that later had to be revoked. For some chemicals no practical field method of analysis exists before a chemical is registered for use. Inspectors are therefore frustrated in their search for residues. This difficulty greatly hampered the work on the "cranberry chemical," aminotriazole. Analytical methods are lacking, too, for certain fungicides in common use for the treatment of seeds — seeds which if unused at the end of the planting season, may very well find their way into human food.

In effect, then, to establish tolerances is to authorize contamination of public food supplies with poisonous chemicals in order that the farmer and the processor may enjoy the benefit of cheaper production — then to penalize the consumer by taxing him to maintain a policing agency to make certain that he shall not get a lethal dose. But to do the policing job properly would cost money beyond any legislator's courage to appropriate, given the present volume and toxicity of agricultural chemicals. So in the end the luckless consumer pays his taxes but gets his poisons regardless.

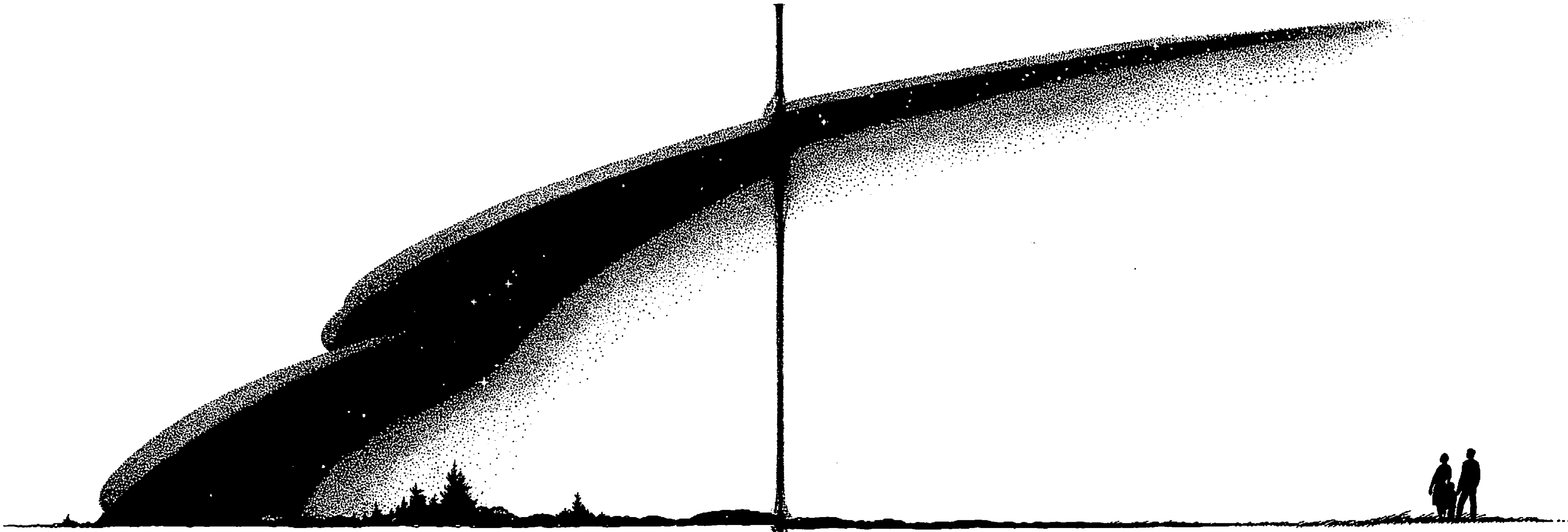
What is the solution? The first necessity is the elimination of tolerances on the chlorinated hydrocarbons, the organic phosphorus group, and other highly toxic chemicals. It will immediately be objected that this will place an intolerable burden on the farmer. But if, as is now the presumable goal, it is possible to use chemicals in such a way that they leave a residue of only 7 parts per million (the tolerance for DDT), or of 1 part per million (the tolerance for parathion), or even of only 0.1 part per million as is required for dieldrin on a great variety of fruits and vegetables, then why is it not possible, with only a little more care, to prevent the occurrence of any residues at all? This, in fact, is what is required for some chemicals such as heptachlor, endrin, and dieldrin on certain crops. If it is considered practical in these instances, why not for all?

But this is not a complete or final solution, for a zero tolerance on paper is of little value. At present, as we have seen, more than 99 per cent of the interstate food shipments slip by without inspection. A vigilant and aggressive Food and Drug Administration, with a greatly increased force of inspectors, is another urgent need.

This system, however — deliberately poisoning our food, then policing the result — is too reminiscent of Lewis Carroll's White

Knight who thought of "a plan to dye one's whiskers green, and always use so large a fan that they could not be seen." The ultimate answer is to use less toxic chemicals so that the public hazard from their misuse is greatly reduced. Such chemicals already exist: the pyrethrins, rotenone, ryania, and others derived from plant substances. Synthetic substitutes for the pyrethrins have recently been developed, and some of the producing countries stand ready to increase the output of the natural product as the market may require. Public education as to the nature of the chemicals offered for sale is sadly needed. The average purchaser is completely bewildered by the array of available insecticides, fungicides, and weed killers, and has no way of knowing which are the deadly ones, which reasonably safe.

In addition to making this change to less dangerous agricultural pesticides, we should diligently explore the possibilities of nonchemical methods. Agricultural use of insect diseases, caused by a bacterium highly specific for certain types of insects, is already being tried in California, and more extended tests of this method are under way. A great many other possibilities exist for effective insect control by methods that will leave no residues on foods (see Chapter 17). Until a large-scale conversion to these methods has been made, we shall have little relief from a situation that, by any common-sense standards, is intolerable. As matters stand now, we are in little better position than the guests of the Borgias.



12. The Human Price

As THE TIDE of chemicals born of the Industrial Age has arisen to engulf our environment, a drastic change has come about in the nature of the most serious public health problems. Only yesterday mankind lived in fear of the scourges of smallpox, cholera, and plague that once swept nations before them. Now our major concern is no longer with the disease organisms that once were omnipresent; sanitation, better living conditions, and new drugs have given us a high degree of control over infectious disease. Today we are concerned with a different kind of hazard that lurks in our environment — a hazard we ourselves have introduced into our world as our modern way of life has evolved.

The new environmental health problems are multiple — created by radiation in all its forms, born of the never-ending stream of chemicals of which pesticides are a part, chemicals now pervading the world in which we live, acting upon us directly and indirectly, separately and collectively. Their presence casts a shadow that is no less ominous because it is formless and obscure, no less frightening because it is simply impossible to predict the effects of lifetime exposure to chemical and physical agents that are not part of the biological experience of man.

"We all live under the haunting fear that something may corrupt the environment to the point where man joins the dinosaurs as an obsolete form of life," says Dr. David Price of the United States Public Health Service. "And what makes these thoughts all the more disturbing is the knowledge that our fate could perhaps be sealed twenty or more years before the development of symptoms."

Where do pesticides fit into the picture of environmental disease? We have seen that they now contaminate soil, water, and food, that they have the power to make our streams fishless and our gardens and woodlands silent and birdless. Man, however much he may like to pretend the contrary, is part of nature. Can he escape a pollution that is now so thoroughly distributed throughout our world?

We know that even single exposures to these chemicals, if the amount is large enough, can precipitate acute poisoning. But this is not the major problem. The sudden illness or death of farmers, spraymen, pilots, and others exposed to appreciable quantities of pesticides are tragic and should not occur. For the population as a whole, we must be more concerned with the delayed effects of absorbing small amounts of the pesticides that invisibly contaminate our world.

Responsible public health officials have pointed out that the biological effects of chemicals are cumulative over long periods of time, and that the hazard to the individual may depend on the

sum of the exposures received throughout his lifetime. For these very reasons the danger is easily ignored. It is human nature to shrug off what may seem to us a vague threat of future disaster. "Men are naturally most impressed by diseases which have obvious manifestations," says a wise physician, Dr. René Dubos, "yet some of their worst enemies creep on them unobtrusively."

For each of us, as for the robin in Michigan or the salmon in the Miramichi, this is a problem of ecology, of interrelationships, of interdependence. We poison the caddis flies in a stream and the salmon runs dwindle and die. We poison the gnats in a lake and the poison travels from link to link of the food chain and soon the birds of the lake margins become its victims. We spray our elms and the following springs are silent of robin song, not because we sprayed the robins directly but because the poison traveled, step by step, through the now familiar elm leaf–earthworm–robin cycle. These are matters of record, observable, part of the visible world around us. They reflect the web of life — or death — that scientists know as ecology.

But there is also an ecology of the world within our bodies. In this unseen world minute causes produce mighty effects; the effect, moreover, is often seemingly unrelated to the cause, appearing in a part of the body remote from the area where the original injury was sustained. "A change at one point, in one molecule even, may reverberate throughout the entire system to initiate changes in seemingly unrelated organs and tissues," says a recent summary of the present status of medical research. When one is concerned with the mysterious and wonderful functioning of the human body, cause and effect are seldom simple and easily demonstrated relationships. They may be widely separated both in space and time. To discover the agent of disease and death depends on a patient piecing together of many seemingly distinct and unrelated facts developed through a vast amount of research in widely separated fields.

We are accustomed to look for the gross and immediate effect and to ignore all else. Unless this appears promptly and in such obvious form that it cannot be ignored, we deny the existence of hazard. Even research men suffer from the handicap of inadequate methods of detecting the beginnings of injury. The lack of sufficiently delicate methods to detect injury before symptoms appear is one of the great unsolved problems in medicine.

"But," someone will object, "I have used dieldrin sprays on the lawn many times but I have never had convulsions like the World Health Organization spraymen — so it hasn't harmed me." It is not that simple. Despite the absence of sudden and dramatic symptoms, one who handles such materials is unquestionably storing up toxic materials in his body. Storage of the chlorinated hydrocarbons, as we have seen, is cumulative, beginning with the smallest intake. The toxic materials become lodged in all the fatty tissues of the body. When these reserves of fat are drawn upon the poison may then strike quickly. A New Zealand medical journal recently provided an example. A man under treatment for obesity suddenly developed symptoms of poisoning. On examination his fat was found to contain stored dieldrin, which had been metabolized as he lost weight. The same thing could happen with loss of weight in illness.

The results of storage, on the other hand, could be even less obvious. Several years ago the *Journal* of the American Medical Association warned strongly of the hazards of insecticide storage in adipose tissue, pointing out that drugs or chemicals that are cumulative require greater caution than those having no tendency to be stored in the tissues. The adipose tissue, we are warned, is not merely a place for the deposition of fat (which makes up about 18 per cent of the body weight), but has many important functions with which the stored poisons may interfere. Furthermore, fats are very widely distributed in the organs and tissues of the whole body, even being constituents of cell membranes. It is important to remember, therefore, that the fat-soluble insecticides become stored in individual cells, where they are in position to interfere with the most vital and necessary functions of oxidation and energy production. This important aspect of the problem will be taken up in the next chapter.

One of the most significant facts about the chlorinated hydrocarbon insecticides is their effect on the liver. Of all organs in the body the liver is most extraordinary. In its versatility and in the indispensable nature of its functions it has no equal. It presides over so many vital activities that even the slightest damage to it is fraught with serious consequences. Not only does it provide bile for the digestion of fats, but because of its location and the special circulatory pathways that converge upon it the liver receives blood directly from the digestive tract and is deeply involved in the metabolism of all the principal foodstuffs. It stores sugar in the form of glycogen and releases it as glucose in carefully measured quantities to keep the blood sugar at a normal level. It builds body proteins, including some essential elements of blood plasma concerned with blood-clotting. It maintains cholesterol at its proper level in the blood plasma, and inactivates the male and female hormones when they reach excessive levels. It is a storehouse of many vitamins, some of which in turn contribute to its own proper functioning.

Without a normally functioning liver the body would be disarmed — defenseless against the great variety of poisons that continually invade it. Some of these are normal by-products of metabolism, which the liver swiftly and efficiently makes harmless by withdrawing their nitrogen. But poisons that have no normal place in the body may also be detoxified. The "harmless" insecticides malathion and methoxychlor are less poisonous than their relatives only because a liver enzyme deals with them, altering their molecules in such a way that their capacity for harm is lessened. In similar ways the liver deals with the majority of the toxic materials to which we are exposed.

Our line of defense against invading poisons or poisons from within is now weakened and crumbling. A liver damaged by pesticides is not only incapable of protecting us from poisons, the whole wide range of its activities may be interfered with. Not only are the consequences far-reaching, but because of their variety and the fact that they may not immediately appear they may not be attributed to their true cause.

In connection with the nearly universal use of insecticides that are liver poisons, it is interesting to note the sharp rise in hepatitis that began during the 1950's and is continuing a fluctuating climb. Cirrhosis also is said to be increasing. While it is admittedly difficult, in dealing with human beings rather than laboratory animals, to "prove" that cause A produces effect B, plain common sense suggests that the relation between a soaring rate of liver disease and the prevalence of liver poisons in the environment is no coincidence. Whether or not the chlorinated hydrocarbons are the primary cause, it seems hardly sensible under the circumstances to expose ourselves to poisons that have a proven ability to damage the liver and so presumably to make it less resistant to disease.

Both major types of insecticides, the chlorinated hydrocarbons and the organic phosphates, directly affect the nervous system, although in somewhat different ways. This has been made clear by an infinite number of experiments on animals and by observations on human subjects as well. As for DDT, the first of the new organic insecticides to be widely used, its action is primarily on the central nervous system of man; the cerebellum and the higher motor cortex are thought to be the areas chiefly affected. Abnormal sensations as of prickling, burning, or itching, as well as tremors or even convulsions may follow exposure to appreciable amounts, according to a standard textbook of toxicology.

Our first knowledge of the symptoms of acute poisoning by DDT was furnished by several British investigators, who deliberately exposed themselves in order to learn the consequences. Two scientists at the British Royal Navy Physiological Laboratory invited absorption of DDT through the skin by direct contact with walls covered with a water-soluble paint containing 2 per cent DDT, overlaid with a thin film of oil. The direct effect on the nervous system is apparent in their eloquent description of their symptoms: "The tiredness, heaviness, and aching of limbs were very real things, and the mental state was also most distressing . . . [there was] extreme irritability . . . great distaste for work of any sort . . . a feeling of mental incompetence in tackling the simplest mental task. The joint pains were quite violent at times."

Another British experimenter who applied DDT in acetone solution to his skin reported heaviness and aching of limbs, muscular weakness, and "spasms of extreme nervous tension." He took a holiday and improved, but on return to work his condition deteriorated. He then spent three weeks in bed, made miserable by constant aching in limbs, insomnia, nervous tension, and feelings of acute anxiety. On occasion tremors shook his whole body — tremors of the sort now made all too familiar by the sight of birds poisoned by DDT. The experimenter lost 10 weeks from his work, and at the end of a year, when his case was reported in a British medical journal, recovery was not complete.

(Despite this evidence, several American investigators conducting an experiment with DDT on volunteer subjects dismissed the complaint of headache and "pain in every bone" as "obviously of psychoneurotic origin.")

There are now many cases on record in which both the symptoms and the whole course of the illness point to insecticides as the cause. Typically, such a victim has had a known exposure to one of the insecticides, his symptoms have subsided under treatment which included the exclusion of all insecticides from his environment, and most significantly *have returned with each* *renewed contact* with the offending chemicals. This sort of evidence — and no more — forms the basis of a vast amount of medical therapy in many other disorders. There is no reason why it should not serve as a warning that it is no longer sensible to take the "calculated risk" of saturating our environment with pesticides.

Why does not everyone handling and using insecticides develop the same symptoms? Here the matter of individual sensitivity enters in. There is some evidence that women are more susceptible than men, the very young more than adults, those who lead sedentary, indoor lives more than those leading a rugged life of work or exercise in the open. Beyond these differences are others that are no less real because they are intangible. What makes one person allergic to dust or pollen, sensitive to a poison, or susceptible to an infection whereas another is not is a medical mystery for which there is at present no explanation. The problem nevertheless exists and it affects significant numbers of the population. Some physicians estimate that a third or more of their patients show signs of some form of sensitivity, and that the number is growing. And unfortunately, sensitivity may suddenly develop in a person previously insensitive. In fact, some medical men believe that intermittent exposures to chemicals may produce just such sensitivity. If this is true, it may explain why some studies on men subjected to continuous occupational exposure find little evidence of toxic effects. By their constant contact with the chemicals these men keep themselves desensitized — as an allergist keeps his patients desensitized by repeated small injections of the allergen.

The whole problem of pesticide poisoning is enormously complicated by the fact that a human being, unlike a laboratory animal living under rigidly controlled conditions, is never exposed to one chemical alone. Between the major groups of insecticides, and between them and other chemicals, there are interactions that have serious potentials. Whether released into

soil or water or a man's blood, these unrelated chemicals do not remain segregated; there are mysterious and unseen changes by which one alters the power of another for harm.

There is interaction even between the two major groups of insecticides usually thought to be completely distinct in their action. The power of the organic phosphates, those poisoners of the nerve-protective enzyme cholinesterase, may become greater if the body has first been exposed to a chlorinated hydrocarbon which injures the liver. This is because, when liver function is disturbed, the cholinesterase level drops below normal. The added depressive effect of the organic phosphate may then be enough to precipitate acute symptoms. And as we have seen, pairs of the organic phosphates themselves may interact in such a way as to increase their toxicity a hundredfold. Or the organic phosphates may interact with various drugs, or with synthetic materials, food additives — who can say what else of the infinite number of man-made substances that now pervade our world?

The effect of a chemical of supposedly innocuous nature can be drastically changed by the action of another; one of the best examples is a close relative of DDT called methoxychlor. (Actually, methoxychlor may not be as free from dangerous qualities as it is generally said to be, for recent work on experimental animals shows a direct action on the uterus and a blocking effect on some of the powerful pituitary hormones — reminding us again that these are chemicals with enormous biologic effect. Other work shows that methoxychlor has a potential ability to damage the kidneys.) Because it is not stored to any great extent when given alone, we are told that methoxychlor is a safe chemical. But this is not necessarily true. If the liver has been damaged by another agent, methoxychlor is stored in the body at *100 times* its normal rate, and will then imitate the effects of DDT with long-lasting effects on the nervous system. Yet the liver damage that brings this about might be so slight as to pass unnoticed. It might have been the result of any of a number of commonplace situations — using another insecticide, using a cleaning fluid containing carbon tetrachloride, or taking one of the so-called tranquilizing drugs, a number (but not all) of which are chlorinated hydrocarbons and possess power to damage the liver.

Damage to the nervous system is not confined to acute poisoning; there may also be delayed effects from exposure. Long-lasting damage to brain or nerves has been reported for methoxychlor and others. Dieldrin, besides its immediate consequences, can have long delayed effects ranging from "loss of memory, insomnia, and nightmares to mania." Lindane, according to medical findings, is stored in significant amounts in the brain and functioning liver tissue and may induce "profound and long lasting effects on the central nervous system." Yet this chemical, a form of benzene hexachloride, is much used in vaporizers, devices that pour a stream of volatilized insecticide vapor into homes, offices, restaurants.

The organic phosphates, usually considered only in relation to their more violent manifestations in acute poisoning, also have the power to produce lasting physical damage to nerve tissues and, according to recent findings, to induce mental disorders. Various cases of delayed paralysis have followed use of one or another of these insecticides. A bizarre happening in the United States during the prohibition era about 1930 was an omen of things to come. It was caused not by an insecticide but by a substance belonging chemically to the same group as the organic phosphate insecticides. During that period some medicinal substances were being pressed into service as substitutes for liquor, being exempt from the prohibition law. One of these was Jamaica ginger. But the *United States Pharmacopeia* product was expensive, and bootleggers conceived the idea of making a substitute Jamaica ginger. They succeeded so well that their spurious product responded to the appropriate chemical tests

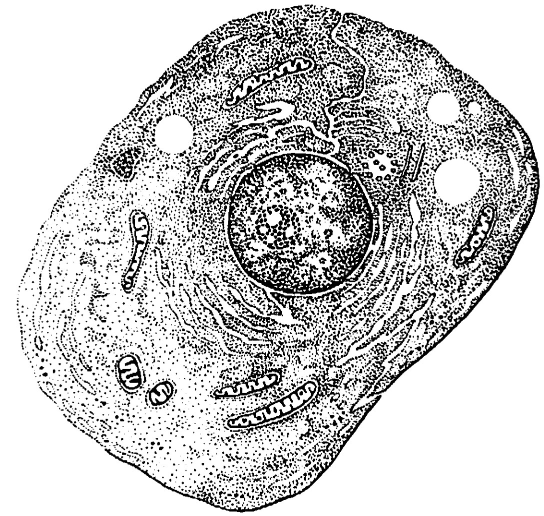
and deceived the government chemists. To give their false ginger the necessary tang they had introduced a chemical known as triorthocresyl phosphate. This chemical, like parathion and its relatives, destroys the protective enzyme cholinesterase. As a consequence of drinking the bootleggers' product some 15,000 people developed a permanently crippling type of paralysis of the leg muscles, a condition now called "ginger paralysis." The paralysis was accompanied by destruction of the nerve sheaths and by degeneration of the cells of the anterior horns of the spinal cord.

About two decades later various other organic phosphates came into use as insecticides, as we have seen, and soon cases reminiscent of the ginger paralysis episode began to occur. One was a greenhouse worker in Germany who became paralyzed several months after experiencing mild symptoms of poisoning on a few occasions after using parathion. Then a group of three chemical plant workers developed acute poisoning from exposure to other insecticides of this group. They recovered under treatment, but ten days later two of them developed muscular weakness in the legs. This persisted for 10 months in one; the other, a young woman chemist, was more severely affected, with paralysis in both legs and some involvement of the hands and arms. Two years later when her case was reported in a medical journal she was still unable to walk.

The insecticide responsible for these cases has been withdrawn from the market, but some of those now in use may be capable of like harm. Malathion (beloved of gardeners) has induced severe muscular weakness in experiments on chickens. This was attended (as in ginger paralysis) by destruction of the sheaths of the sciatic and spinal nerves.

All these consequences of organic phosphate poisoning, if survived, may be a prelude to worse. In view of the severe damage they inflict upon the nervous system, it was perhaps inevitable that these insecticides would eventually be linked with mental disease. That link has recently been supplied by investigators at the University of Melbourne and Prince Henry's Hospital in Melbourne, who reported on 16 cases of mental disease. All had a history of prolonged exposure to organic phosphorus insecticides. Three were scientists checking the efficacy of sprays; 8 worked in greenhouses; 5 were farm workers. Their symptoms ranged from impairment of memory to schizophrenic and depressive reactions. All had normal medical histories before the chemicals they were using boomeranged and struck them down.

Echoes of this sort of thing are to be found, as we have seen, widely scattered throughout medical literature, sometimes involving the chlorinated hydrocarbons, sometimes the organic phosphates. Confusion, delusions, loss of memory, mania — a heavy price to pay for the temporary destruction of a few insects, but a price that will continue to be exacted as long as we insist upon using chemicals that strike directly at the nervous system.



13. Through a Narrow Window

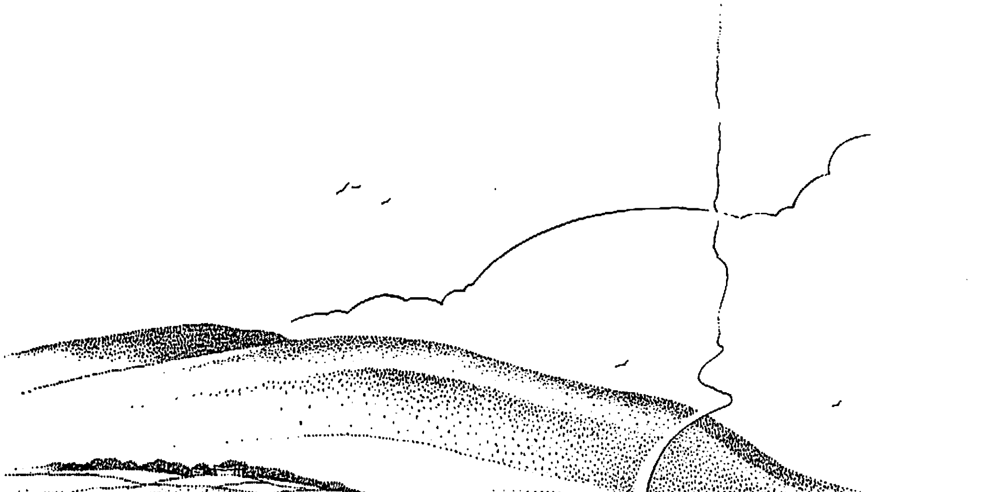
The biologist George Wald once compared his work on an exceedingly specialized subject, the visual pigments of the eye, to "a very narrow window through which at a distance one can see only a crack of light. As one comes closer the view grows wider and wider, until finally through this same narrow window one is looking at the universe."

So it is that only when we bring our focus to bear, first on the individual cells of the body, then on the minute structures within the cells, and finally on the ultimate reactions of molecules within these structures — only when we do this can we comprehend the most serious and far-reaching effects of the

17. The Other Road

WE STAND NOW where two roads diverge. But unlike the roads in Robert Frost's familiar poem, they are not equally fair. The road we have long been traveling is deceptively easy, a smooth superhighway on which we progress with great speed, but at its end lies disaster. The other fork of the road — the one "less traveled by" — offers our last, our only chance to reach a destination that assures the preservation of our earth.

The choice, after all, is ours to make. If, having endured



much, we have at last asserted our "right to know," and if, knowing, we have concluded that we are being asked to take senseless and frightening risks, then we should no longer accept the counsel of those who tell us that we must fill our world with poisonous chemicals; we should look about and see what other course is open to us.

A truly extraordinary variety of alternatives to the chemical control of insects is available. Some are already in use and have achieved brilliant success. Others are in the stage of laboratory testing. Still others are little more than ideas in the minds of imaginative scientists, waiting for the opportunity to put them to the test. All have this in common: they are *biological* solutions, based on understanding of the living organisms they seek to control, and of the whole fabric of life to which these organisms belong. Specialists representing various areas of the vast field of biology are contributing — entomologists, pathologists, geneticists, physiologists, biochemists, ecologists — all pouring their knowledge and their creative inspirations into the formation of a new science of biotic controls.

"Any science may be likened to a river," says a Johns Hopkins biologist, Professor Carl P. Swanson. "It has its obscure and unpretentious beginning; its quiet stretches as well as its rapids; its periods of drought as well as of fullness. It gathers momentum with the work of many investigators and as it is fed by other streams of thought; it is deepened and broadened by the concepts and generalizations that are gradually evolved."

So it is with the science of biological control in its modern sense. In America it had its obscure beginnings a century ago with the first attempts to introduce natural enemies of insects that were proving troublesome to farmers, an effort that sometimes moved slowly or not at all, but now and again gathered speed and momentum under the impetus of an outstanding success. It had its period of drought when workers in applied entomology, dazzled by the spectacular new insecticides of the

1940's, turned their backs on all biological methods and set foot on "the treadmill of chemical control." But the goal of an insect-free world continued to recede. Now at last, as it has become apparent that the heedless and unrestrained use of chemicals is a greater menace to ourselves than to the targets, the river which is the science of biotic control flows again, fed by new streams of thought.

Some of the most fascinating of the new methods are those that seek to turn the strength of a species against itself — to use the drive of an insect's life forces to destroy it. The most spectacular of these approaches is the "male sterilization" technique developed by the chief of the United States Department of Agriculture's Entomology Research Branch, Dr. Edward Knipling, and his associates.

About a quarter of a century ago Dr. Knipling startled his colleagues by proposing a unique method of insect control. If it were possible to sterilize and release large numbers of insects, he theorized, the sterilized males would, under certain conditions, compete with the normal wild males so successfully that, after repeated releases, only infertile eggs would be produced and the population would die out.

The proposal was met with bureaucratic inertia and with skepticism from scientists, but the idea persisted in Dr. Knipling's mind. One major problem remained to be solved before it could be put to the test — a practical method of insect sterilization had to be found. Academically, the fact that insects could be sterilized by exposure to X-ray had been known since 1916, when an entomologist by the name of G. A. Runner reported such sterilization of cigarette beetles. Hermann Muller's pioneering work on the production of mutations by X-ray opened up vast new areas of thought in the late 1920's, and by the middle of the century various workers had reported the sterilization by X-rays or gamma rays of at least a dozen species of insects.

ing on the species, may devour up to 800! This may result, according to laboratory tests, in destruction of 75 to 98 per cent of the cocoons present.

It is not surprising that the island of Newfoundland, which has no native shrews but is beset with sawflies, so eagerly desired some of these small, efficient mammals that in 1958 the introduction of the masked shrew — the most efficient sawfly predator — was attempted. Canadian officials report in 1962 that the attempt has been successful. The shrews are multiplying and are spreading out over the island, some marked individuals having been recovered as much as ten miles from the point of release.

There is, then, a whole battery of armaments available to the forester who is willing to look for permanent solutions that preserve and strengthen the natural relations in the forest. Chemical pest control in the forest is at best a stopgap measure bringing no real solution, at worst killing the fishes in the forest streams, bringing on plagues of insects, and destroying the natural controls and those we may be trying to introduce. By such violent measures, says Dr. Ruppertshofen, "the partnership for life of the forest is entirely being unbalanced, and the catastrophes caused by parasites repeat in shorter and shorter periods . . . We, therefore, have to put an end to these unnatural manipulations brought into the most important and almost last natural living space which has been left for us."

Through all these new, imaginative, and creative approaches to the problem of sharing our earth with other creatures there runs a constant theme, the awareness that we are dealing with life — with living populations and all their pressures and counter-pressures, their surges and recessions. Only by taking account of such life forces and by cautiously seeking to guide them into channels favorable to ourselves can we hope to achieve a reasonable accommodation between the insect hordes and ourselves.

The current vogue for poisons has failed utterly to take into account these most fundamental considerations. As crude a weapon as the cave man's club, the chemical barrage has been hurled against the fabric of life — a fabric on the one hand delicate and destructible, on the other miraculously tough and resilient, and capable of striking back in unexpected ways. These extraordinary capacities of life have been ignored by the practitioners of chemical control who have brought to their task no "high-minded orientation," no humility before the vast forces with which they tamper.

The "control of nature" is a phrase conceived in arrogance, born of the Neanderthal age of biology and philosophy, when it was supposed that nature exists for the convenience of man. The concepts and practices of applied entomology for the most part date from that Stone Age of science. It is our alarming misfortune that so primitive a science has armed itself with the most modern and terrible weapons, and that in turning them against the insects it has also turned them against the earth.