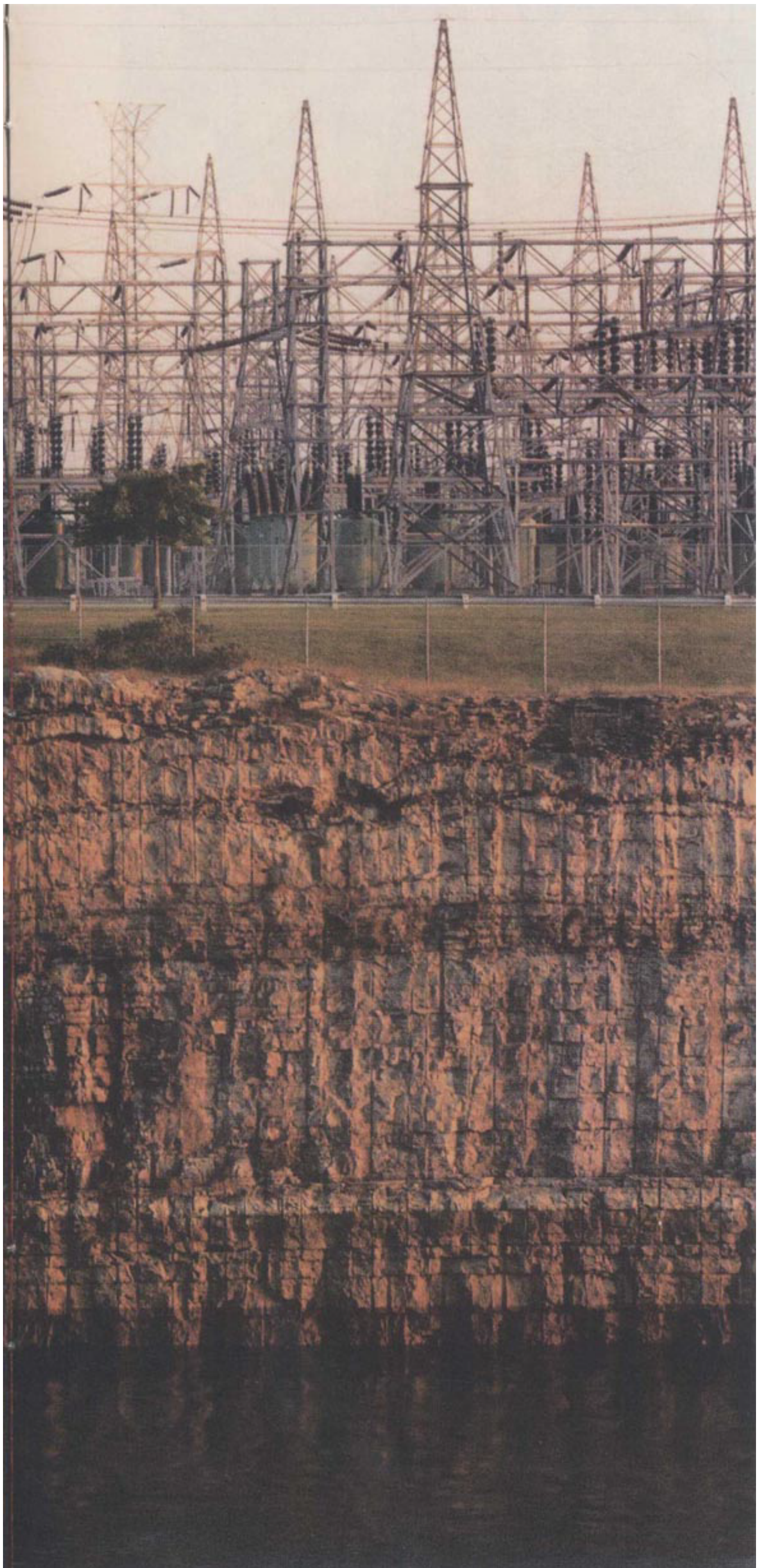
THE ENERGY AROUND US

John Pfhal, Niagara Power Project, Niagara Falls, New York, *1981* *by* W. Ross Adey

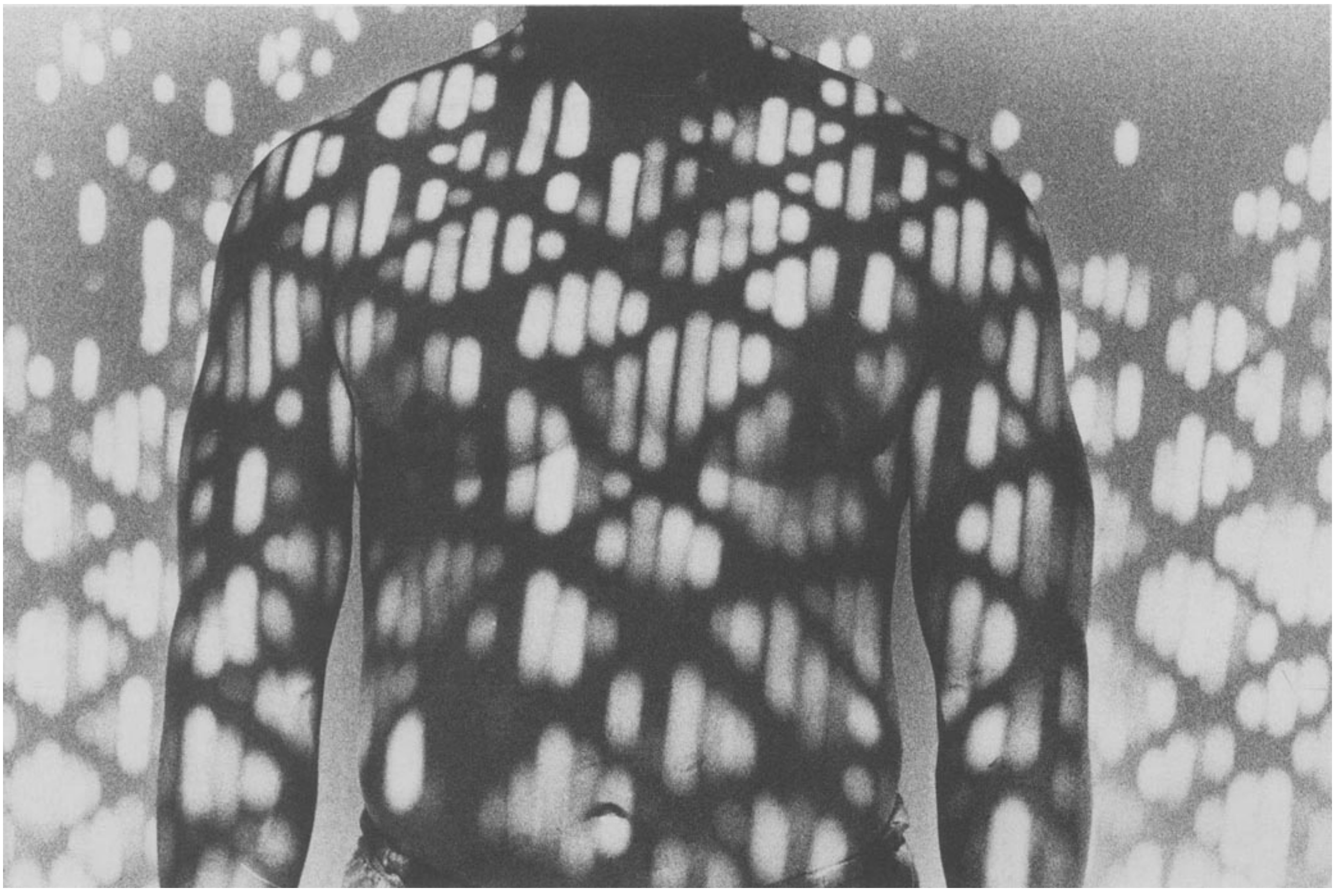


THE BODY ELECTRIC
Electromagnetism and the Foundation of Life
by Robert O. Becker and Gary Selden
William Morrow and Company; 364 pages; $17.95

THE MICROWAVE DEBATE
by Nicholas H. Steneck
The MIT Press; 279 pages; $27.50

Since the turn of the century, we have seen an exponential growth in the application of electomagnetic energy to societal needs. From light bulbs to microwave ovens, from satellite dishes to cellular telephones, devices that emit electromagnetic radiation have earned a place in our homes and workplaces. A natural unease with things ill understood has fueled concern that this burgeoning technology is a health hazard. Some speak of electromagnetic pollution and electronic smog. Because an understanding of the physical and biological laws necessary for informed consideration of the issue is simply not possible for a great majority of the voting citizens and their chosen lawmakers, these fears have often assumed unwarranted proportions. Residents of Staten Island, in New York, for example, have protested the proposed construction of a microwave transmitter that would emit less than a single watt of power. Such superstitions are all the more disconcerting because they obscure a valid question: Do we face a future fraught with widespread dangers simply by reason of our refusal to recognize threats from man-made alterations in the electromagnetic environment?

Over the past ten years, three interest groups have arrayed themselves to do battle over this question. On one side are the fervent, if poorly organized activists who maintain that some workplaces and homes are already polluted to a hazardous degree. They cite high levels of electromagnetic radiation in some factories, near airport radar installations and satellite uplink transmitters, and around the clusters of radio and television transmitters found in many suburbs, sometimes directly above dwellings. Even the daily use of electric blankets and hair dryers, they warn, may have deleterious effects, either on the user or on an unborn child. Standing in opposition to these claims are the electric utilities and electronic consumer product industries. They have taken the strong and entrenched position, at least until recently, that there is no basis for public concern and no credible evidence that would support a reduction in existing levels of exposure. Finally, there is the less overt but enormously powerful influence of groups within the military establishment that oversee radar and other high-powered communications systems in this country and abroad. No monolithic view exists within the Department of Defense, but Pentagon officials fear, in the name of national security, any reduction in the capabilities of these communications systems,



Ralph Gibson, Untitled, Morocco, *1983*

whatever the implications for public health.

Why does the controversy persist? Surely, in such an enlightened age, there can be no doubt about the essential nature of the effect of so-called nonionizing electromagnetic fields on the tissues of organisms. But the lack of a broad and credible data base is indeed the nub of the problem and serves as the backdrop for two new books with quite different perspectives on the dangers posed by electromagnetic radiation. Notwithstanding the present ignorance, *The Body Electric* and *The Microwave Debate* both reflect, to one degree or another, a heartening development: we are in the midst of one of the greatest conceptual revolutions in the history of science, and it promises to fill this knowledge gap.

AT THE HEART of this issue is a conflict between two fundamentally different ways of looking at the communication within and among cells that controls their daily functioning: the equilibrium viewpoint and the nonequilibrium viewpoint. An example from a distant realm will help demonstrate the distinction. Consider a tabletop with dominoes scattered about it, most of them lying flat and a few standing on their edges. The dominoes are, in some sense, at equilibrium: they are in a natural, more or less randomly organized state, and no great expenditure of energy has been made to impart a particular structure to them. Imagine that you want to "send a signal" from one side of the table to the other—to change the positions of the dominoes on the far side by touching one or more dominoes on the near side. How much force must be exerted? A considerable amount. It would take a fairly broad and forceful sweep of your hand and forearm to induce so much motion that not a single domino on the far side of the table would escape its influence. Now suppose that the dominoes are not randomly organized but are standing on their ends in a configuration that will allow you, by toppling one domino on the near side of the table, to topple all the dominoes.

The first of these scenarios corresponds to the equilibrium view of cellular communication, which holds that a large expenditure of energy is required to overcome the noise, or randomly arranged energy, within a cell and to convey a message to the cell's interior that will significantly affect its functioning. The second scenario corresponds to the nonequilibrium view, which holds that information can be conveyed across a cell's membrane with a very low expenditure of energy. Of course, there is a sense in which this scenario involves a high expenditure: much energy is consumed in preparing the dominoes to be toppled, by placing them in a highly structured, nonequilibrium state, and the same is true of the cell membrane. Further, that energy must be expended again in preparation for each signal to be so transmitted. Nonetheless, both on a tabletop and along a cell membrane, this high initial investment of energy yields an important benefit: it enables a small additional expenditure to initiate significant communication.

For more than thirty years the equilibrium view has held sway in biology. Nobel Prizes in profusion have been bestowed on those who produced evidence that signaling across the cell membrane entails a large expenditure of energy, and their acolytes have dutifully indoctrinated succeeding generations in these ecclesiasticisms. They have seen flood tides of ions bursting across cell membrane boundaries as the sole, sufficient means of signaling and as the basic step in excitation, whether of a cortical neuron involved in forming a sentence, a nerve fiber that initiates a reflex, or a glandular cell that secretes a hormone. All have been lumped under a single rubric in the sheer brutishness of equilibrium models.

Engineering and industrial interests—in particular, power utilities and manufacturers of home appliances and other electrical equipment—have a big stake in these models. If the cell membrane can be penetrated by only large amounts of energy, the only potentially dangerous tissue interactions are thermal interactions—those that raise the temperature of the tissue by at least one-tenth of a degree centigrade. But if nonequilibrium phenomena are in fact important, and slight expenditures of energy can trigger communication, cellular functioning can be significantly affected, and perhaps impaired, by athermal tissue interactions, which involve no appreciable change in temperature. Safety standards based on nonequilibrium considerations would require the acceptance of sharply lower exposure levels than would thermal standards.

This country's first medical guidelines for human exposure to electromagnetic radiation were developed by the military during the late 1950s. The three major armed forces agreed that exposure to radiation with a frequency of up to ten milliwatts per square centimeter could be presumed safe. In other words, if the radiation lacked the energy to fry your cells, it could not hurt you. The perspective was that of the physicist, who is concerned solely with equilibrium thermodynamics and convinced that only thermal tissue interactions are important.

The past several decades have seen the gradual accumulation of a diverse and incontrovertible body of evidence indicating that far more sensitive mechanisms are involved, that a broad range of electromagnetic radiation has important effects on the functioning of cells. These effects not only occur at low levels of energy but are in some cases very sensitive to subtle changes in the low frequency (below one hundred hertz) of the energy source. For example, the ability of some lymphocytes (white blood cells) to destroy tumor cells is less pronounced in a microwave field modulated at sixty hertz than in a microwave field with a higher or lower modulation frequency. Some enzymes in these lymphocytes are more likely to catalyze certain reactions at sixteen hertz than at, say, five or twenty-five hertz. Such acute responsiveness to electromagnetic radiation occurs across a wide spectrum of cells, in the brain and the pancreas as well as the ovary; even the rate of bone growth has been shown to vary with slight changes in the electromagnetic environment. These sensitivities may be a general biological property; they may represent an intrinsic language of tissue by which cells "whisper together."

If so, this language is of no small importance. Studies have shown that electromagnetic fields can modify at least three main enzyme systems: one concerned with releasing energy from metabolic fuel; another that forms the great intracellular messenger system; and a third that is essential for normal cell growth and is disturbed in malignant growth. In short, intrinsic and environmental electromagnetic fields, whose significance has for years been minimized by the biological establishment, may figure centrally in the most essential functions of life.

THE EVIDENCE on which this conclusion rests has been won slowly and patiently by a small band of investigators, among them Robert O. Becker, coauthor, with free-lance writer Gary Selden, of *The Body Electric.* Becker's essentially autobiographical account is written for a lay audience, and to the uninitiated it offers a well-connected story, with experiments described in an appropriate sequence and with attractive if sometimes simplistic graphics. Thus, the story of our growing understanding of the pervasive role of electromagnetism in the body's functioning unfolds in neat and interesting fashion, beginning in the 1930s, with the embryologist Paul Weiss's iconoclastic research into what he called the morphogenetic field, and continuing to the present day.

But there is a rub, indeed there are many rubs in this tale. To begin with, there is scarcely a pause for breath as the reader progresses from one shining postulate to another. Becker's account is untempered with the caution essential to responsible interpretation of experimental data or with any consideration of the contingencies of experimental design. More serious, perhaps, are problems of credibility. To be sure, the work with which Becker is most closely associated—the use of electromagnetic fields to accelerate the healing process—is competently presented. We see that the healing of fractures can be accelerated by implanting electrodes in the bone and passing an electrical current through it or by bathing the bone in an electromagnetic field. We learn too that the healing of wounds may be facilitated by directing silver ion complexes into the affected cells. But when Becker moves beyond his realm of experience, much is seriously flawed, either in concept or in statements of simple fact. For example, we are told that the "60-cycle alternating current in the wall socket isn't used up when we turn on a light but is merely coursing through it to the ground, through which it eventually returns to the power station." In fact, because of both safety and engineering considerations, ground-return power systems have not been permitted for more than fifty years. The current returns through a neutral wire via the same route that conveyed it to the house. Such an error may seem trivial, but it makes the credibility of biological scientists difficult to sustain in the eyes of engineers and physicists.

At least as troubling are Becker's semiconductor models of tissue organization. On the basis of experiments with salamanders placed in magnetic fields, he argues that it is useful to view large regions of the body as if they were composed of some semiconductor material, such as silicon. In addition to overlooking a number of more plausible models that would also explain the experimental results, this line of argument attributes a simple, homogeneous texture to tissues that are in fact complex and elaborate, composed of millions of discrete cells, each a very complicated device. If the behavior of semiconductors *is* characteristic of tissue, the sources of this behavior must be sought not at the level of the tissue as a whole but at the cellular and subcellular levels. This, Becker has consistently failed to do. He perpetuates the simplistic popular notion of the cell membrane as some sort of chamois bag, whose function is merely to contain the cellular contents and occasionally permit the passage of nutrients. Indeed, he offers no detailed discussion of the profound reciprocal relationships between the cell membrane and the intracellular structures, the subtle and continuous two-way communication that governs cell differentiation and growth. By and large, he appears either unaware or unaccepting of broad new knowledge in cell biology that is highly relevant to any assessment of the risks of field exposure. Becker is a surgeon by training, and here the ultimately pragmatic nature of his research becomes apparent; though he has helped document the exquisite sensitivity of cells to electromagnetic radiation, he has paid scant attention to the implications of these findings for our understanding of cellular functioning.

All these criticisms might be moot had Becker been content to document the importance of electromagnetism in the body's functioning. But he goes further and ventures a number of gloomy prognostications about damage that may be inflicted by electromagnetic radiation, including the kinds of therapeutic uses of pulsed electromagnetic fields that he helped establish. His claim that such therapies may be "nurturing seeds of cancer" is not grounded in any of the accepted models of the disease. For example, the initiation of cancer is conventionally divided into two stages: induction, during which a cell's DNA is altered so as to predispose the cell toward malignancy, and promotion, during which the malignancy may manifest itself. Becker's finding that therapeutic electromagnetic fields can speed the growth of cultured cells *already* malignant says nothing about induction or promotion. Here, as elsewhere, he fails to place his arguments in the context of contemporary knowledge.

This is not to deny a link between electromagnetic radiation and cancer. Credible researchers have found growing evidence that long-term exposure may indeed promote certain cancers, possibly by affecting the immune and endocrine systems. Nonetheless, other findings (dismissed by Becker, on dubious grounds to say the least) suggest a *reduced* cancer growth rate in animals after exposure to electromagnetic fields. Further, preliminary evidence suggests that certain bone cancers may actually be impeded by electromagnetic radiation. Thus, if electromagnetism threatens to cause or accelerate cancer under certain circumstances, it promises to slow or end it in others, and it would be foolish to impose a ban on the relevant research until those circumstances are well defined. More generally, we must recognize the trade offs involved in banning any diagnostic or therapeutic procedure of proven efficacy. Nuclear magnetic resonance imaging, which yields a picture of the body tremendously more subtle and useful than an X ray, has doubtless saved lives. And pulsed laser diodes can minimize scarring of burned tissue. An indiscriminate ban on such electromagnetic therapies would entail costs that must be balanced against possible benefits.

It is not clear what Becker hoped to accomplish in sowing the seeds of wild speculation, solemnly proposing that electropollution may be responsible not just for some cases of cancer but for "an onslaught of 'new' ailments," including Reye's syndrome, Lyme disease, Legionnaire's disease, AIDS, and herpes genitalis. This recklessness only exacerbates an already strained relationship between the popular media and all who retain a sense of the profound importance of cautious, balanced, and even conservative public utterances on such matters. And after all, every one of us is a layman with respect to some important aspect of high technology's impact on society.

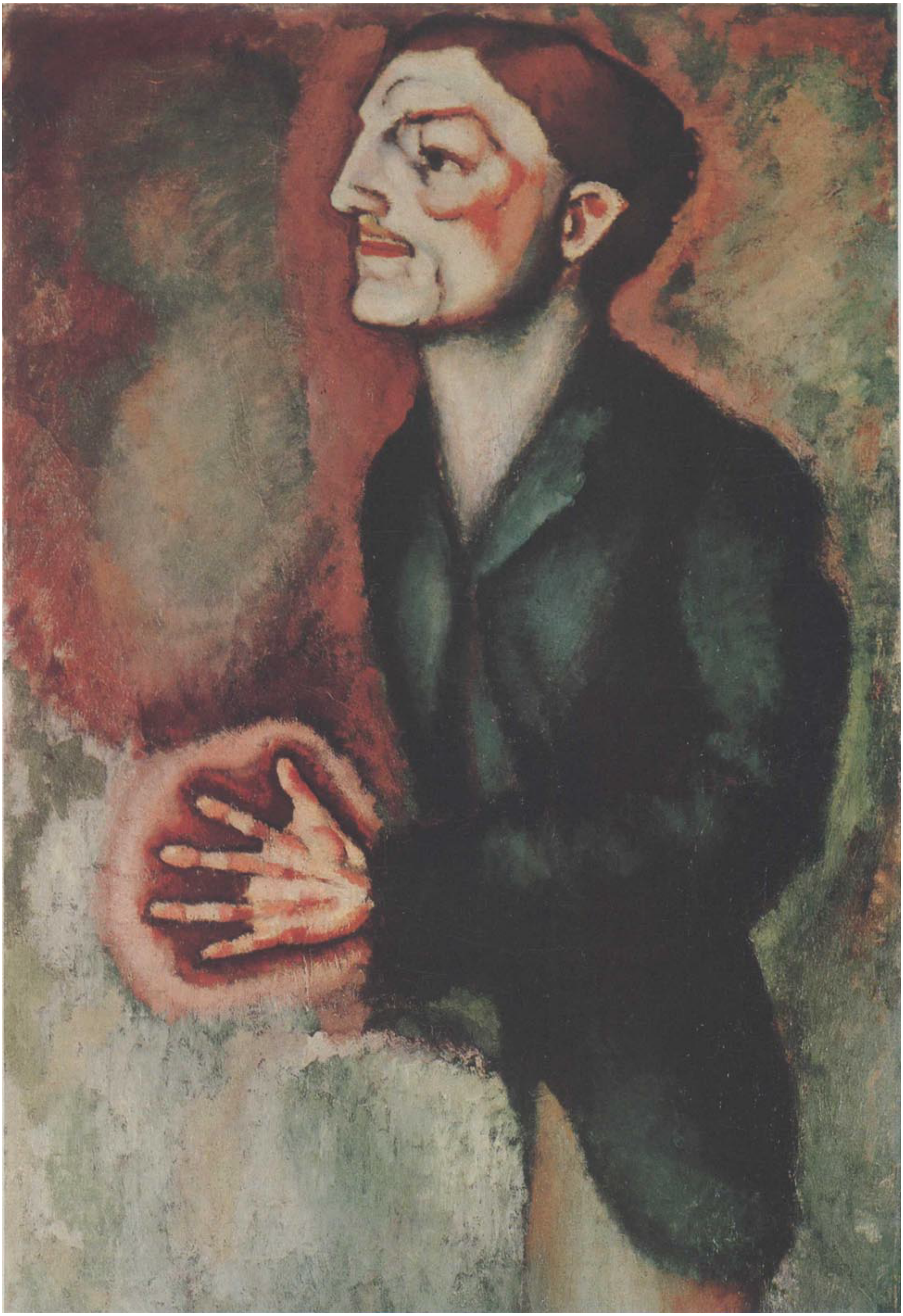
CAN THE HISTORIAN offer a more sober view of this societal dilemma or perhaps point toward new avenues of research? Nicholas H. Steneck, in *The Microwave Debate,* claims to "have used the tools of history to bring order to our understanding of the past and ongoing development of the microwave debate." Order indeed—but at the price of accuracy. Steneck has, regrettably, practiced the historian's trade faithfully; in search of a neatly packaged overview, he trivializes and distorts.

A single example will illustrate. Among the episodes recounted by Steneck is the discovery, during the 1950s, that the Soviet Union was directing a beam of low-intensity microwave radiation at the U.S. embassy in Moscow. The subsequent American evaluation of the dangers posed by the radiation is presented by Steneck as a deep schism between two entrenched factions—one concerned with athermal effects, the other with thermal effects. The fact is that no such split existed; knowledge then was too primitive to permit such a distinction. The debate was dominated by shades of gray; it consisted not of factions battling but of scientists feeling their way painstakingly and uncertainly from the unknown to the known.

Even after Steneck's account reaches the point in history when the debate over athermal effects had in fact assumed sharp form, the reader is left in the dark as to its substance. This is a grave weakness. Steneck's whole case rests on his contention that athermal field effects are important and that our understanding of this has been stymied by "barriers to athermal thinking." Yet his treatment of the subject stops short at trivial anecdotes from the medical and military literature of long ago. The elegant beauty of all we have learned about cellular and molecular biology through the use of athermal fields as research tools has escaped him completely.

The power of these new concepts is beyond comparison; they betoken a biological revolution of vast proportions that will touch every basic area of cellular biology, from the development of embryonic form to aging and cancer. It will entail a thorough deciphering of the intricate communications between the cell surface and the nucleus, with its DNA, and a thorough understanding of the way the electromagnetic "whispering" among cells is amplified into louder "talking" to pass through the electric barrier of the cell membrane to the interior, which is dense with high-energy communication.

From a synthesis of research in laboratories worldwide, a picture has already emerged of the essential steps in this amplification. Central to the process are negatively charged strands of protein that protrude from the fatty layer of the cell membrane (they somewhat resemble a field of waving corn) and serve as the cell's main electrochemical sensor. First, a packet of electromagnetic energy—generated by another cell or perhaps at the cell membrane by a chemical reaction—loosens a few ions of the calcium bound to the protein strands, a loosening that



Marcel Duchamp, Dr. Dumouchel, *1910*

rapidly spreads across the entire surface of the cell in a kind of domino effect. In some cases, this triggers a second such rapid reaction—an enzymatic brushfire that also encompasses the entire cell surface. The signal originally embodied in electromagnetic energy, thus amplified, passes across the membrane to the cell's interior. It is not yet clear what form the signal is now in, but there is plausible evidence that it travels down the strands of helical protein molecules that pass through the membrane.

Signals from electromagnetic fields reaching the interior of the cell have at least two main effects. They can alter the structure of the cytoskeleton—the fine tubes and fibers that convey signals from the cell membrane to the nucleus and other tiny bodies within the cell. And they can alter the activity of key enzyme systems that regulate growth, metabolism, and intercellular communication.

The study of this process leads ultimately to the common ground of biology and physics, where a search has begun for elemental aspects of molecular and atomic behavior. Among the surprising preliminary findings is that atoms and molecules are not always randomly organized but sometimes structure themselves into clusters of atomic and subatomic particles that form tiny packets of vibrational and electrical energy. These packets may travel as solitons, or solitary waves, conveying energy or signals within and among cells. (It is the solitons, some believe, that traverse the cell membrane along the helical strands of protein.) In short, the study of nonequilibrium systems in biology is one of those rare events in the history of science that dissolve the barriers between disciplines. Physicists and biochemists will walk this road together, and what they find is likely to alter ideas in both fields.

WHY HAVE Becker and Steneck failed to convey—indeed, it seems, to comprehend—this revolution while purporting to base their arguments on it? The answer lies in their conviction that this line of research has been stymied by political forces. Steneck maintains that "the scientific community has allowed social, economic, and political pressures to influence its activities, thereby destroying the credibility of its product." Becker depicts his own work as if it were as much military as intellectual, as much a struggle against some plot to repress his findings as a struggle against ignorance.

This perspective is grounded in Becker's central role in documenting the significance of athermal tissue interactions. Workers in this field have been touched by high excitement, but also by a deep sense of isolation from the conventional research philosophies that guide national scientific platforms and determine research funding. It is not an exaggeration to say that these pioneering bands of scientists have operated for years in a state of siege, ostracized from the mainstreams of biological research on one hand and, on the other, locked in mortal combat with the giants of industry, who have sought without scruple to discredit them. It is not surprising that those who experienced such resistance to honest discussion of the dangers of electromagnetic radiation would become preoccupied with those dangers and with depicting the sources of that resistance as misguided, even conspiratorial. Yet, it is sad that Becker, who defiantly stood his ground for so many years and may now stand on the brink of vindication, should spend more time recounting the grants he was denied by adverse political currents than exploring the deep implications of his work. That bitterness taints this book and, in the eyes of many readers, will discredit it.

While Becker and Steneck were busy looking in closets for conspirators, others have been assembling an accurate, if still incomplete picture of the dangers posed by electromagnetic fields in the environment. The typical home probably is safe, but there are reasons for caution. Excessive leakage from microwave ovens, for example, could well be dangerous, affecting the immune system in a way that may weaken resistance to cancer. But the majority of these devices meet existing safety standards throughout their lifetimes. There is no evidence linking such household items as hair dryers and electric blankets to cancer. Still, when findings suggest that man-made electromagnetic fields far weaker than the earth's magnetic field can alter the development of an embryo, caution is warranted. Prudence also demands continuing scrutiny of houses in close proximity to high-voltage power lines and high-powered radio and television stations, as well as such microwave sources as airport radar installations and satellite uplink transmitters. There is growing epidemiological evidence that these environments may be associated in the long term with significant health problems. In a variety of industrial environments employing powerful sources of electromagnetic energy, research will almost certainly lead to more rigorous regulations. One study has shown that the children of men with occupational exposure to strong electromagnetic fields were eleven times more likely than the average child to have a certain type of tumor of the nervous system. Other studies suggest that television repairmen, even ham radio operators, have a higher than average risk of cancer. No one of these studies provides unequivocal evidence of a hazard, but together they constitute an overwhelming case for prudence in long-term human exposure. Despite unfavorable political winds, science will continue to unravel these problems.

Steneck, of course, does not share this faith. The history of establishing radio-frequency settings, he writes, "does not necessarily lead to the conclusion that problem solving is best begun by assembling more scientific data on RF [radio-frequency and microwave radiation] bioeffects." Rather, Steneck suggests that we put our faith in outside observers—political scientists, economists, historians, philosophers, and others who "are not committed to specific fields of scientific research" and can therefore interpret data dispassionately. This is a palpable absurdity. This area of research is one of the most intrinsically arcane in human experience, and no good will be served by subordinating it to those, like Steneck, who are incapable of comprehending it. Nor is any service performed by those, like Becker, whose creative genius has been eroded by preoccupation with the frailty of human relations and by the ill-founded perception of pervasive hazards. Perhaps a future writer will dignify this subject with the intellectual challenge it so richly deserves. ●

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