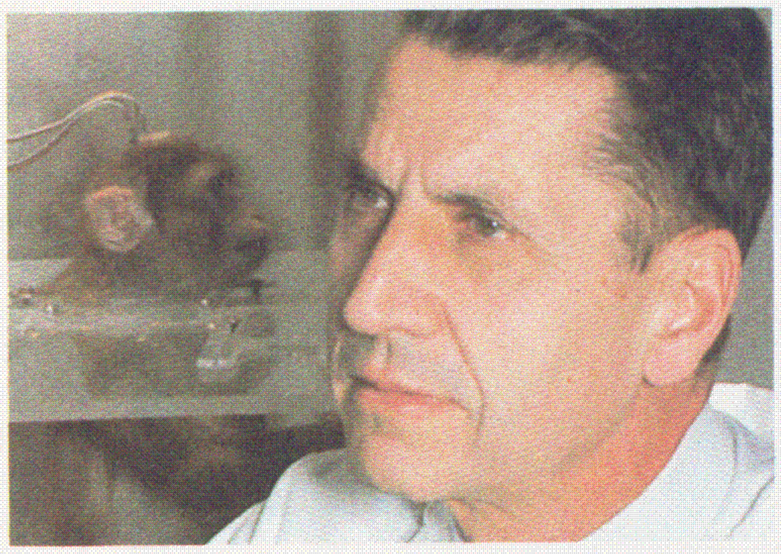
José Delgado's invisible energy pulses control the behavior of animals. What power do they hold over us?

THE MIND FIELDS

BY KATHLEEN McAULIFFE



The film crew prepares to shoot as three monkeys are strapped into high chairs. Each animal has a metallic coil—a sort of high-tech halo—suspended above its head. The signal is given, and two of the monkeys' hoops begin pulsing with electromagnetic energy. It is an anticlimactic moment, with none of the crackling fireworks that heralded Frankenstein's debut. Neither the eye nor hand can detect even the faintest trace of a field in the vicinity of the activated coils. The animals appear completely unaffected.

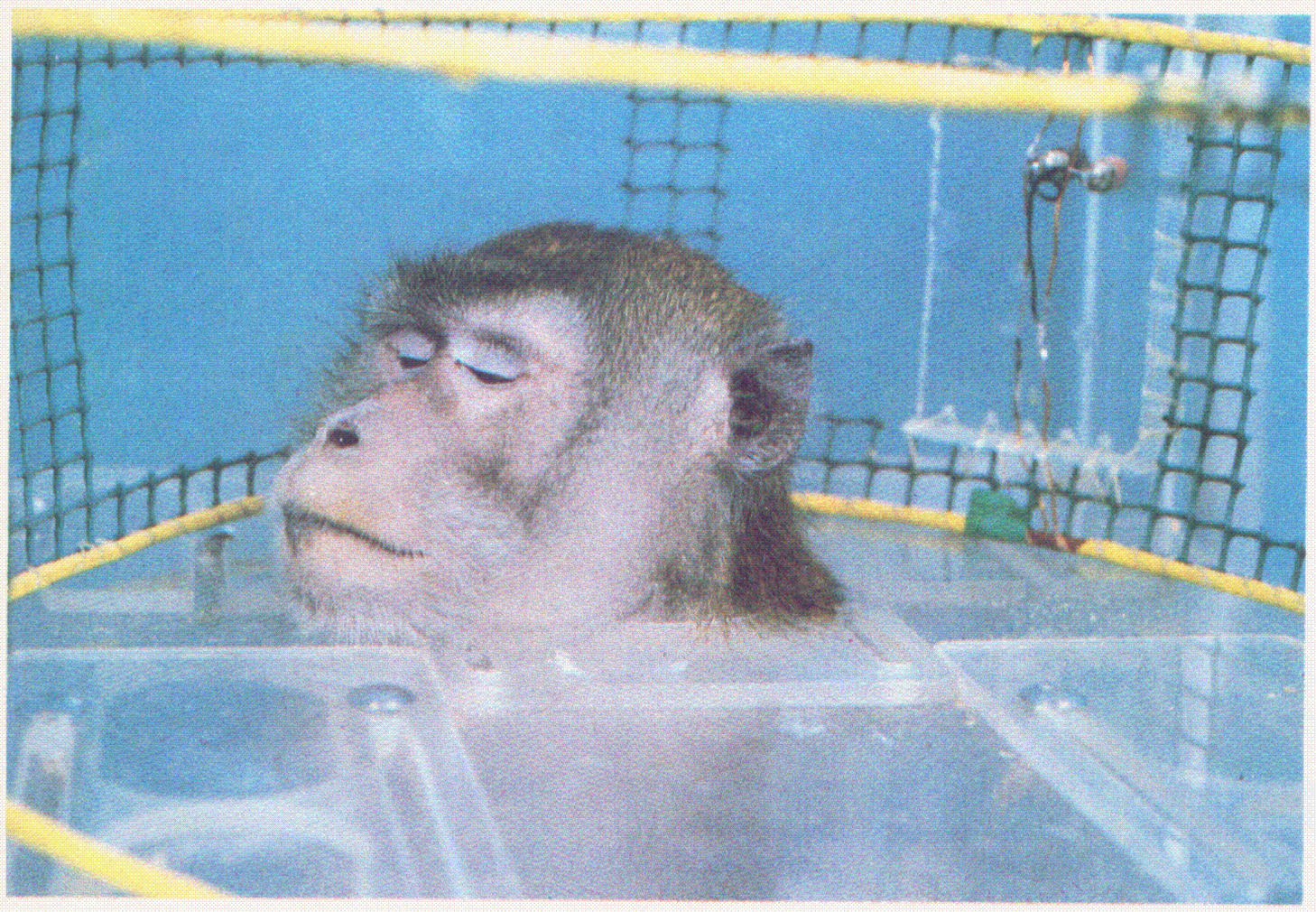
But after less than an hour, differences are plainly visible. Despite the presence of glaring lights, cameramen, and sound technicians, one monkey has dozed off. The monkey next to him, whose coils were never turned on, remains calm but alert. And the third monkey, exposed to more rapidly pulsing fields than the first, is biting the air and squirming to break loose from its chair.

José Delgado, internationally famous neuroscientist, has done it again. For the greater part of the Sixties, the Spanish showman of science dazzled—and in some instances frightened or outraged—the research community with his spectacular demonstrations showing how behavior can be modified by implanting electrodes in the brains of cats, chimps, and even humans. Using this technique to stimulate different brain regions, Delgado found that it was possible to evoke complex behavior patterns—research that prompted some to liken him to a puppeteer pulling strings. As a legendary tribute to his faith in technology, he even confronted a charging bull. As the 1,000-pound, horned beast lunged at him, Delgado used a radio signal to activate an electrode deep in the animal's brain, bringing it to a halt at Delgado's feet.

But now he has begun working with another technology. It doesn't require pressing electrodes into brain tissue. In fact, the equipment need not touch experimental animals at all. Instead, Delgado's subjects today are placed within an electromagnetic field (EMF) where, even without direct brain contact, their behavior changes.

PAINTING BY MARSHALL ARISMAN

"Under the influence of different electromagnetic fields, one monkey sleeps while another becomes hyperactive in José Delgado's Madrid laboratory."



All of us are surrounded by waves of electromagnetic energy. But we can see only visible light, whose wavelengths range from 375 billionths to 775 billionths of a meter. As poet William Blake put it, we view the world "through a narrow chink." We're blind to X rays and other energies with wavelengths shorter than one billionth of a meter. Nor can human sight detect energy with wavelengths longer than light—we can't see the emanations from a police radar, the energy halos around a TV transmitting tower, a VHF radio antenna, or an A.C. power line (whose energy has a wavelength of roughly 10,000 kilometers). Yet each of these devices produces electromagnetic fields. Researchers have also been able to detect EMFs in the brain and around the dense network of the body's nerves. The earth itself produces such fields. If human eyes were more sensitive, astronauts could watch our planet shimmer around its perimeter, glowing brightest at the poles.

The fields Delgado uses are as low as one fiftieth the strength of the earth's own magnetic fields. Your body would be subject to a more intense bombardment of energy if you stood under a fluorescent light. Yet when the signal is tuned to precise frequencies (with long wavelengths in roughly the same range as power-line waves), Delgado can do much more than make a monkey sleepy.

As we set out on a tour of the 100-room, ultramodern Ramon y Cajal hospital complex, in Madrid, it quickly becomes apparent that his research staff is using the same infinitesimal fields to produce astoundingly diverse effects in virtually every species investigated. One team demonstrates that they can pacify fighting fish, inhibiting the feisty predator from attacking its image in a mirror. Other groups are using the fields to thwart the growth of bacteria, to speed healing of rats' bone fractures, and to change the migratory movements of snails.

The invisible force has also produced some alarming results. Chick embryos incubated in the fields became grossly deformed, and a colony of fruit flies suffered an increased incidence of a lethal genetic mutation.

For years, scientists have known that at high levels, these fields "heat up" the body. But scientists have assumed that living organisms are not sensitive to low levels of this ghostly energy. Delgado's work is only the latest in a series of recent findings that overturn this cherished belief. For better or worse, weak electromagnetic fields are emerging as a potent biological force—a discovery with staggering implications for the future of medicine, science, industry, and perhaps even the military. For example:

- Doctors in Europe and the United States are planning to harness imperceptible fields to correct abnormal heart rhythms and to control such conditions as epilepsy—from *outside* the body. Furthermore, these fields will be used to promote healing of skin, nerves, and tendons.
- Studies suggest that these same invisible fields may have deleterious effects. Preliminary reports hint that video display terminals (VDTs), power lines, microwave appliances, and other sources of environmental electromagnetism may not be as benign as once thought.
- There is growing concern among experts that EMFs have been—or will be—deployed as invisible weapons to disrupt brain functioning and health.

Delgado is much more low-key about the ramifications of his work. An elegant man in his early sixties, he speaks slowly, careful to express his thoughts with precision. For all his bravado in the bullring, Delgado is not the sort of scientist who shoots from the hip.

"Our first goal is to understand how we are getting these effects—we know so little," he says in English embellished by the cultured flair of a Spanish accent.

"Then we may want to explore whether the fields can help people suffering from motor disturbances, depression, and other psychoneurotic disorders."

To pursue this goal, his lab is developing new types of brain instrumentation. In addition to the head coils, the Cajal team is testing the effects of tiny transmitters that permit EMFs to be beamed more precisely to targets in the brain. No larger than a watch battery, the transmitter is inserted into a tight-fitting hood that slips like a bathing cap over the animal's head.

In one recent study, Delgado tested the device on a monkey that had electrodes—vestiges of his previous work—implanted in two separate regions of its motor cortex. Before the trial began, he demonstrated how activating the first electrode caused the animal to clench its fist. Activating the second electrode triggered an eye blink. Then the animal's head was capped with a hood containing a transmitter aimed at the cerebellum, a structure in the lower hind part of the brain. Several hours later, the special hood was removed, and the electrodes were activated again. There was a marked difference in the animal's evoked response. What was once a mere blink of the eye had become a wince involving the eyebrow and cheek muscles. And the clenched fist had been transformed into a jerk of the entire lower arm.

Encouraged by these results, Delgado has several ongoing experiments with hooded monkeys, whose brains are being activated by tiny transmitters as the primates roam freely through their spacious cages in the basement of the laboratory. It may be a long time, however, before Delgado fully understands how the EMF transmitter produces its effects. "Much more research will have to be done," Delgado says. "But with further knowledge, I am hopeful that without surgery or drugs, we will eventually be able to correct abnormal brain activity in humans."

Remarkably, these EMFs are several hundred times below the voltage needed for an electrode to trigger a nerve to fire. According to theory, they should have no impact. Yet when Delgado aims these fields at an isolated crab neuron already firing at a specific, steady rate, something surprising happens: The neuron changes its firing rate to synchronize with the applied pulses, much as a child sleeping with his mother will begin breathing at the same rate as the parent. This phenomenon is known as entrainment.

Researchers have observed similar entrainment effects in the neurons of the cerebral cortices of live animals. This suggests that the phenomenon may play an important role in normal brain function. A team headed by W. Ross Adey, a neuroscientist at the Veterans Administration Hospital, in Loma Linda, California, has shown that the brain waves of monkeys tend to become "locked" in phase with external fields tuned to the same frequency band as the brain waves.

For example, if the animal's head is placed in a field pulsing at the same rhythm as alpha—a natural brain rhythm associated with relaxation in humans—its brain will start to produce more and more alpha. And when the animal's brain waves become entrained to fields pulsing at other brain-wave frequencies, subtle behavioral changes are sometimes detected. In one notable experiment, a monkey's learning and memory retention improved over the course of a simple lever-pressing trial.

To both Delgado and Adey, these experiments indicate that the prevailing theory about how brain cells communicate with one another may be misleading. Popular theory, called the connectivist model, maintains that the brain is nothing more than a complex bundle of circuits. Information travels along discrete nerve pathways that ultimately connect, thus allowing several different inputs to be assimilated. Based on the latest entrainment studies, however, it would appear that nerves lying along separate circuits can respond in unison to information from EMFs.

Although the evidence supporting this theory has only recently been established, the theory itself was put forth several decades ago. "In the early Fifties the great British zoologist J. Z. Young came up with a beautiful analogy for this phenomenon," Adey says. "He likened the brain to a telephone exchange in which operators sit in a row at the switchboard. They see lights flash, and they plug circuits in and pull them out. And in the fashion of operators, they eavesdrop on the conversations. As a result of what they overhear, they whisper together. It is in this whispering together, Young said, that 'I discern the most intrinsic function of the organization of the brain.'

"In other words, it is not the impulses going through the switchboard of the brain that Young thought were of fundamental importance. It was what the operators—the cells—gleaned from the traffic and then communicated among themselves."

Although brain cells are undoubtedly best adapted for "whispering together," a similar phenomenon may occur in other parts of the body. When a large amount of tissue is being regenerated, for example, scientists find that nerves must grow into the wound before the surrounding cells start to divide and organize themselves to repair the damage. A careful examination of this process has led some scientists to postulate that the nerves are generating fields—not unlike the brain's—that signal cells in the injured region to undergo a series of transformations that culminate in tissue replacement. No one currently understands the details of how this signaling occurs—whether during wound healing or during the much more complicated processes that create thoughts in the brain. But most scientists hypothesize that external fields can interact with the body's own fields.

"For better or worse, electromagnetic fields have emerged as a potent force—a discovery with staggering implications for the future of medicine, science, industry, and the military."

Some scientists even speak of a "biological wave band," as if the animal were a radio receiver tuned to pick up certain types of emissions. The frequency, amplitude, and other characteristics of the electromagnetic signal must fall within a certain range before specific effects are observed.

"All the cells that make up living organisms," Delgado explains, "are packed full of highly charged atoms and molecules that may change their orientation and movement in the presence of certain types of fields. This might in turn have an impact on enumerable chemical processes within the cells."

Calcium ions are charged particles that play a vital role in many different types of cellular processes, including the firing of nerve cells. "My work with Dr. Suzanne Bawin," says Adey, "has shown that fields way too weak to trigger a nerve impulse can nevertheless modify the way these charged calcium ions bind [or attach] to the surface of cells, unleashing myriad chemical reactions deep within the cell itself."

Astoundingly, recent evidence indicates that calcium binding to cell surfaces may be influenced not only by fields produced in the laboratory, but by the earth's own magnetic field. This new finding, reported by Dr. Carl Blackman, of the Environmental Protection Agency's Health Effects Research Laboratory, in Research Triangle Park, North Carolina, is causing a stir in scientific circles. After doing calculations based on Blackman's data, physicist Abe Liboff, of Oakland University, in Rochester, Michigan, concludes that the "geomagnetic field may play a previously unrecognized role in the functioning of living organisms." Adey feels it is still too soon to extrapolate from Blackman's data. But he says that when fields alter the way calcium is attached to the cell membrane, the chemical domino effect that starts on the surface may spread to the heart of the cell, where genes reside. If so, the genetic code could be influenced. Could that explain why Delgado's fields disrupted the development of chick embryos and caused lethal mutations in fruit flies?

Delgado does not discount this possibility. But he thinks the fields may also be capable of interacting directly with DNA—without any intermediate chemical steps involved. "Our understanding of genetics is very clumsy at present," Delgado says. "But if we can produce lethal mutations with the fields, perhaps we will someday be able to use the technique to produce beneficial gene changes."

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MIND FIELDS

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Already, Andrew Bassett and colleagues Reba Goodman and Ann Henderson, of Columbia Presbyterian Medical Center, in New York City, have demonstrated that specific types of fields can enhance the way certain fruit-fly genes manifest themselves.

"We're sitting on the edge of genetic engineering," Bassett says. "It's a very powerful tool that—if used properly—can be of enormous help in the clinic. But like any other technology, it can be dangerous if applied in a willy-nilly fashion."

If nothing else, such experiments should force public-health experts to reconsider the impact of EMFs on humans. Here, it would seem, is a remote system for controlling cells—to accelerate or diminish growth, alter physiology and behavior, and perhaps even change the genetic material itself. "If Delgado's findings can be replicated by independent researchers, it's absolutely incredible," says Richard Tell, of the EPA, in Atlanta. "On the one hand, I hope like heck he's wrong, because it will mean reevaluating assumptions about the safety of video display terminals and other sources of environmental electromagnetism. On the other hand, I pray he's right because the medical applications—not to mention the scientific implications—are so intriguing."

Louis Slesin, editor of *Microwave News*, concurs: "There's genuine astonishment over some of these effects. It seems that electromagnetic fields are capable of influencing living organisms in ways no one would have previously believed."

Perhaps it's because these effects are so unexpected that electromagnetic medicine is still struggling to be recognized. Doctors have treated approximately 50,000 patients with coils to mend intractable bone fractures. But to many physicians, the notion that imperceptible fields can radically alter living organisms is still akin to witchcraft. Likewise, many dismiss as excessive paranoia the possibility that weak sources of electromagnetic energy in the environment could affect people adversely.

It's hardly surprising that the biology of electromagnetism has grown up under a cloud of controversy and intrigue. Mystery still surrounds the strangely allied powers of electricity and magnetism. When a magnet is moved along a piece of conducting wire, for example, current will flow in the wire. Conversely, if current is moving along a wire, the space immediately surrounding it becomes magnetized. Everyone knows there is *something* in that space. Hold a compass up to the wire, as Hans Christian Oersted did back in 1820, and the needle will be deflected. But even today we are far from certain what that something is.

With physicists so baffled by these basic phenomena, the foundations of modern medicine have invariably come to rest squarely on surgery and drugs. Yet during the past decade, a few brave doctors did venture into this murky domain.

While their understanding is far from precise, what they discovered convinced them that electromagnetism could revolutionize medical practice—and not just in treating brain disorders.

At Technic Research Laboratories, in San Leandro, California, for example, magnetic fields are being explored as a tool for regulating arrhythmic hearts. "We look at each organ in the body as resonating at a specific frequency," explains William Van Bise, Technic's chief of biomedical research. The firm currently has a patent pending for the first wireless cardiac pacemaker used outside the body. A tiny transmitter, it generates magnetic fields that stabilize the firing pattern of the special cells that keep the heart beating. If the device is successful, cardiac patients will no longer have wires inserted deep into the heart itself. The new model, according to the inventor, Technic president Elizabeth Rauscher, could be worn either as a necklace or implanted just under the skin during a visit to a doctor's office.

"Weak fields are used to heal burns and skin wounds, treat tendonitis, and speed bone mending. Eventually, they may help control epilepsy and other brain disorders."

"Another goal that's on the horizon," Van Bise adds, "is to develop a brain pacemaker that would use similar principles to stabilize dangerous arrhythmias in the brain waves of epileptics. But that remains a more futuristic prospect."

A variety of electromagnetic treatments that evolved from the work of Dr. Robert O. Becker, an orthopedic surgeon recently retired from the Veterans Administration Hospital, in Syracuse, New York, are currently available to patients. In a series of seminal investigations during the Sixties and Seventies, Becker discovered that tiny amounts of current applied to the body could unleash an innate capacity for regenerative growth. Soon he and Columbia Presbyterian's Bassett began implanting electrodes in human-bone fractures that had failed to mend by any other means.

The success of the treatment led a team headed by Bassett to fit electromagnetic coils around plaster casts, thereby inducing currents in the injured area from outside the body. This innovation, approved by the Food and Drug Administration (FDA) in 1979, gave the embryonic field of electromagnetic medicine a much-needed boost.

To heal other body tissues, researchers soon learned that the frequency and other characteristics of the applied field had to be varied. Using one type of field only slightly stronger than Delgado's, Bassett now reports that he can stimulate the growth of new blood vessels to save diseased hips. "When a deep-sea-diving accident, a bad fall, or too much alcohol suddenly cuts off the blood supply to the hip joint," Bassett says, "the victim is stricken with increasing pain, disability, and arthritis at a very young age."

His remedy is to fit the hip with portable coils, which the patient must wear for a minimum of 10 hours a day. The outcome of a multicenter study just completed for the FDA evaluation is impressive. "Less than ten percent of our patients have needed to undergo a total hip replacement," Bassett says. "Before this treatment, eighty-five percent would have ended up in that position."

Cardiac victims may be the next to benefit from this treatment. "I am convinced," Bassett says, "that the principles we have learned from reestablishing the blood supply to a diseased hip could also be applied to patients suffering from cardiac blockages." This approach, he believes, could someday help patients who are now candidates for bypass surgery.

Bassett is equally excited by another therapeutic use of pulsed electromagnetic fields. Collaborating with Dr. Hiromoto Ito, of the Nippon Medical School, in Tokyo, he has shown that the coils can stimulate rats to regrow peripheral nerves (all nerves outside the skull and spinal column) at twice the normal rate, halving the time it takes for recovery of function in the damaged limb. The investigators will embark shortly on human clinical trials.

In Europe, still other intractable conditions in patients are being cured with weak electromagnetic fields. Nicolino Marchetti, at the University of Cacliari, in Pisa, reports that the coils can be "miraculous" at healing severe burns, long-standing diabetic ulcers, and other chronic skin wounds. And in Britain the technology is used for treating tendonitis of the shoulder—a painful, inflammatory condition of the muscles and tendons. Last March, Brian Hazelman, of Addenbrookes Hospital, in Cambridge, announced the outcome of a carefully controlled clinical study of the procedure. In some 85 percent of those outfitted with the coils, symptoms of tendonitis disappeared, and the pain did not return once the treatment was stopped.

While some types of electromagnetic fields act to stimulate growth, others can inhibit it. Delgado's team and several other research groups are presently trying to use coils to stop cancer cells from dividing. So far, however, the outcome of tests on animals with tumors has not been encouraging. Unfortunately, it is a lot easier to make cancer cells multiply than to halt their production.

As for possible untoward effects of low-intensity electromagnetism, Delgado admits to having certain misgivings. "After the chick-embryo study," he says, "I went home to check out the electrical appliances in my

kitchen. Still, it would be premature to get too excited by this. There is always the possibility, but without further evidence, one does not want to exaggerate."

Two months after making these comments, however, Delgado's chick-embryo study became the center of the most intense round to date in the long-standing controversy over the health risks posed by environmental electromagnetism.

Among 12 pregnant workers operating video terminals at the Defense Logistics Agency, in Marietta, Georgia, there were seven miscarriages and three cases of congenital defects. Four VDT operators in the *Toronto Star*'s classified-advertisement department gave birth to deformed children, while three co-workers who did not use VDTs had normal babies. And of 55 pregnant operators of VDTs at the Department of Employment, in Runcorn, England, 22 percent gave birth to malformed babies, 14 percent suffered miscarriages, and 6.7 percent had stillbirths. Among their pregnant colleagues who did not use VDTs, only 11 percent gave birth to malformed babies, 5.4 percent had miscarriages, and fewer than 1 percent had still-births.

Government and industry experts have maintained that the EMFs emitted by these appliances are too weak to be harmful and dismiss such clusters as statistical flukes. As of 1984, however, the number of clusters of problem pregnancies had risen to 15 in the United States, Canada, and Europe. EPA health officials and medical experts hired by electronic companies started scanning the scientific literature for other clues.

That's when Dr. Arthur Guy, a consultant for IBM, came across Delgado's paper reporting that chick embryos exposed to pulsed electromagnetic fields did not develop normally. Director of the Bioelectromagnetics Research Laboratory at the University of Washington's School of Medicine, in Seattle, Guy noted that the fields Delgado's laboratory used were extremely weak—weak enough to fall within the range of VDT radiation. He went back to his lab and checked out terminals made by Digital Equipment Corporation, Hazeltine, Televideo, and others. Meanwhile other researchers, including EPA's Richard Tell, started their own studies. The consensus of the experts is that VDT emissions are similar—though not exactly identical—to the electromagnetic pulses that deformed the chick embryos. "The possibility of biological hazards will have to be explored further," Tell says.

No one claims that VDTs cause miscarriages or birth defects. "These clusterings of problem pregnancies came to our attention mostly through anecdotal reports, so the figures may be exaggerated or simply inaccurate," Tell adds.

Even so, the evidence is compelling enough that the Food and Drug Administration intends to issue a revised policy statement on VDTs. The statement will discuss the mounting data on how low-frequency, low-intensity magnetic fields may affect human health. If the FDA follows through with this plan of action, the agency could find itself embroiled in a bitter, 30-year-old battle over just what constitutes a safe amount of exposure to EMFs. In the opinion of many scientists, acknowledging that such weak fields could pose risks is tantamount to admitting that the government standard for judging the safety of higher-intensity fields—radar and power-line transmissions, for example—may no longer be valid.

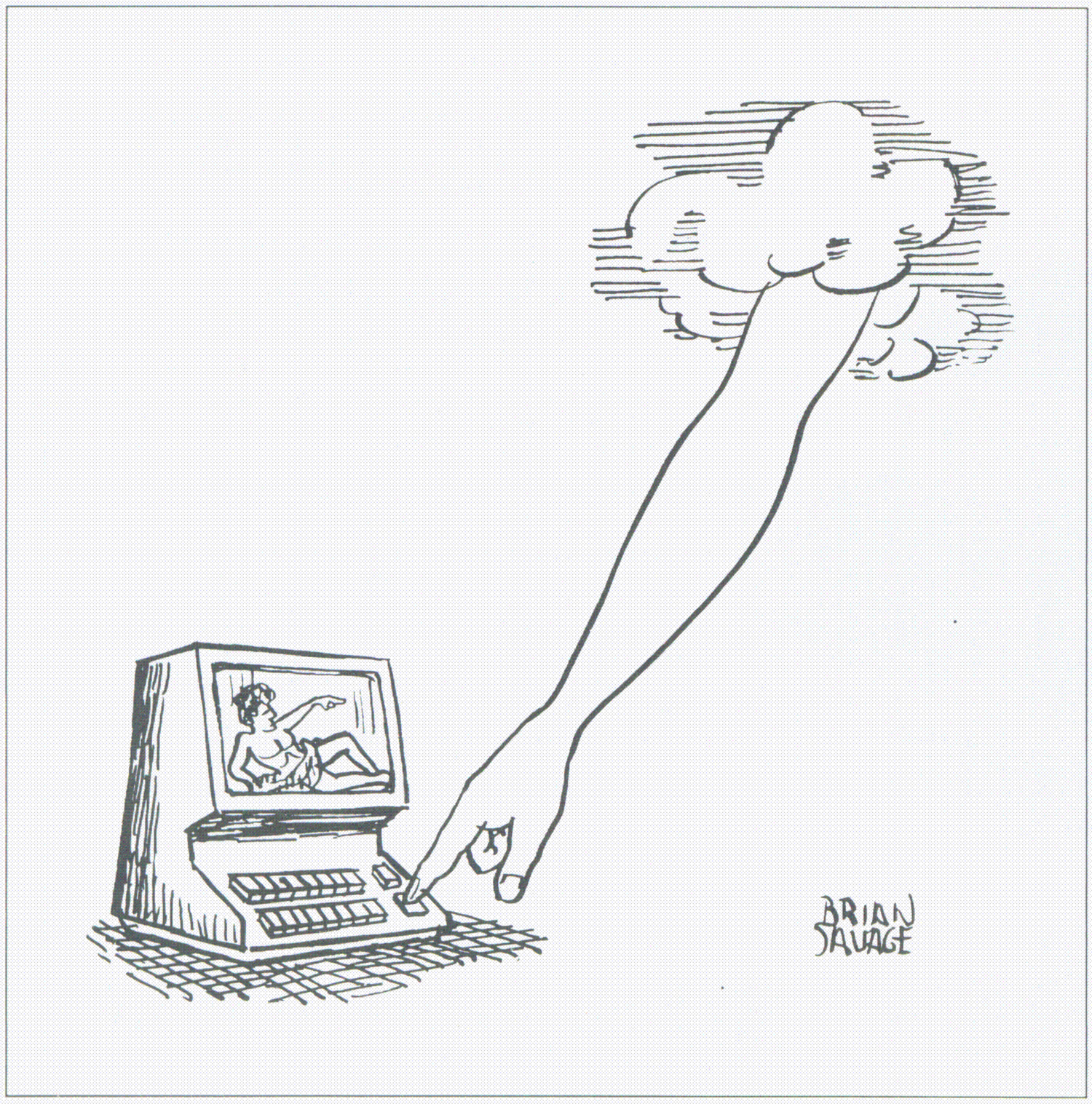
"Everything is coming to a head," says Slesin, the *Microwave News* editor who helped assemble data on VDT emissions. Tell concurs: "I look at the results coming out of Delgado's lab like a nuclear bomb waiting to go off. If his [Delgado's] work is borne out, it opens up a whole range of considerations no one has ever thought of before."

Dr. Becker, an outspoken critic of the government's position on EMF health risks, takes another view. "Delgado is a world-class scientist with outstanding credentials, so he can't be ignored," Becker says. "But the truth of the matter is that this country simply chose to overlook hazards in this area. Take a glance at the Russian literature, and you'll find literally thousands of reports of harmful effects at exposure levels the United States government assures us are safe."

Becker is referring to one of the most bizarre contrasts in the history of modern science. The Russians and the Americans have radically different standards regarding acceptable levels of EMF emissions. This scientific borderline was drawn during the postwar technological boom of the early Fifties, when radar, radio, TV, and other microwave technologies were first being harnessed. In Russia, investigators found that people working around such equipment complained of headaches, loss of appetite, and fatigue—a collection of symptoms called asthenia syndrome. Soviet health officials, whose grounding in the Pavlovian school of psychology predisposed them to study the nervous system and behavior, began their own tests. They exposed rats to fields of lower and lower intensity, noting changes in the animals' conditioned responses.

In time, the results of these and other studies grew into a massive literature that encompasses Russian thinking on some of the deepest mysteries in biological science today. This body of knowledge shaped Soviet theories about brain function, the genetic basis of evolution, the spectacular navigational feats of migratory animals, and the "ticking" mechanism that runs our biological clocks. It also formed the basis for a practical decision—the limit at which the Russians set their safety standard for human exposure to microwaves.

Their American counterparts, on the other hand, tended to discount such mild complaints among microwave workers as subjective and thus "unscientific" evidence. Because these responses were not recorded in technical papers, it was assumed that the



only dangers associated with microwaves resulted from overheating or actually burning tissue. And such effects occur only at much higher power levels. Consequently, American health advisers set tolerance levels for microwave exposure at 10 milliwatts per square centimeter—a power density 1,000 times greater than what the Russians considered safe. This national recommended standard has scarcely been revised since it was first adopted by Air Force personnel in 1957. The standard has also influenced American attitudes about the safety of power-line transmissions and other sources of EMFs that fall in the nonionizing range, that is, below the strength of X rays.

Microwaves differ from X rays, which strip electrons off atoms and turn them into dangerous, charged ions that harm tissue. Microwaves don't have that kind of energy. Their extremely short wavelength, however, makes them the most powerful kind of nonionizing radiation. At high intensities, they can agitate molecules, causing heat. And if heat were all we had to worry about with microwaves, it was assumed that the same would apply for weaker types of nonionizing radiation—radar, TV and radio broadcasts, and the emissions from power lines and VDTs.

The only problem with this theory—called the thermal model—is it fails to take into account one glaring inconsistency: As was well-known to American investigators, the reason the Russians set their safety standard 1,000 times below our own was because they had detected biological effects at levels too low for heating to have caused them. In other words, their findings had led them to abandon the thermal model. This, however, did not bother the U.S. military advisers who, in the Fifties, took the lead in setting standards subsequently adopted by the civilian population. Initially, at least, they were not wrong in assigning little weight to the Russian findings. Tell's criticism of Soviet science today would undoubtedly have also applied to investigations done in the Fifties:

"Their research is so sloppily documented that most of it would not even get published in the West," Tell says. "For example, they'll go into a factory that produces toxic chemicals, has high noise levels, is overheated, and has microwave appliances—and they'll decide that everybody's suffering from some kind of asthenia syndrome. They don't take other confounding variables into account."

What is more difficult to justify 30 years later is why American standard setters never bothered to undertake their own comprehensive program to investigate these claims. The failure is even more striking in light of follow-up Russian reports of much more alarming physiological changes at low-exposure levels. In a 1975 bulletin published by the U.S. Joint Publications Research Service, Soviet scientist A. S. Presman summarized some of these findings:

"Organisms of the most diverse types—from unicellular organisms to man—show various reactions to electromagnetic fields that are thousands, hundreds of thousands, and even millions of times below the intensities one would expect [based on the heating theory]." Presman goes on to list some of these responses: "various disruptions of physiological functions—heart rhythm, blood pressure, and metabolism." In addition, he says that such fields can produce alterations in "visual, acoustic, and tactile sensations in man, as well as emotional states in animals [inducing everything] from suppressed states similar to narcosis to excited states reaching epilepsy. Disruptions in the regulation of development are especially pronounced from the embryonic stage up to the onset of sexual maturity."

Given the lack of data in the West about the effects of low-intensity radiation, you would think these grave assertions might at least trigger some worries. Yet once again the reports were greeted as the extravagant claims of a careless school of science.

After all, what the Russians reported conflicts with practical experience. "The attitude of lots of people inside and outside of government is, 'Hey, microwaves have been around for over thirty years, and electricity, for more than a century; so what's the problem?' " explains Captain Paul Tyler, who served as director of the U.S. Navy's Electromagnetic Radiation Project between 1970 and 1977. "Their contention is, 'Our hair isn't falling out, and we're not all coming down with cancer. Why should we be worried?' "

"Government and industry experts steadfastly maintain that the energy fields emitted by video display terminals are too weak to possibly be harmful."

Such a commonsense—albeit unscientific—argument might be convincing if Delgado's findings were the only evidence that challenged this logic. But sporadic reports of biological hazards at low intensities surfaced in Western literature throughout the Sixties and Seventies. These reports have increased in frequency and have now reached a certain critical mass. Almost overnight, the stream of disconcerting findings is becoming a torrent. For example, Wendell D. Winters, of the University of Texas Health Science Center, in San Antonio, and Jerry L. Phillips, of the neighboring Cancer Research and Therapy Center, reported that exposure to simulated power-line fields produced a fourfold increase of human cancer cells in culture. This was detected 10 to 12 days after one 24-hour exposure.

In a related experiment of much shorter duration, biophysicist Liboff, of Oakland University, exposed both cancerous and healthy mouse cells to much weaker-intensity fields of varying frequencies. A day after the exposure, he discovered that the rate of gene synthesis had increased by 500 percent in the cancerous cells and by as much as 80 percent in the healthy cells.

Animals exposed to radiation from radio waves show subtle changes in blood-cell count, immunity, the nervous system, and behavior, according to a 1984 EPA document that reviews published studies in the area. Most of these effects were observed at intensities below the recommended safety standard for radio-wave exposure. But it's unclear how these findings apply to the general public. Because radiation falls off drastically as distance from the transmitter increases, only a small sector of the population may be receiving radio-wave dosages as high as the animals in the studies. Of particular concern to EPA officials are the individuals who live or work within a radius of about 150 feet of the 1,000 FM transmission towers that have been singled out as trouble spots.

In a University of Washington School of Medicine study funded by the Air Force, Arthur Guy irradiated rats with electromagnetic frequencies carefully designed to simulate exposure levels radar operators themselves experience. The irradiated group showed several signs of immunological stress and developed approximately four times as many tumors as the unexposed control animals.

And then there are the epidemiological studies. Since 1982 a significantly greater incidence of leukemia has been reported in four independent studies of occupational groups exposed to higher-than-usual EMFs—notably, electronic technicians, radio operators, power linemen, power-station operators, repairmen, aluminum smelters, and electrical engineers. The first of these studies was carried out by health epidemiologist Samuel Milham, in Washington State, and the latter surveys were conducted in such divergent geographical locations as Los Angeles, England, and Wales. All the reports were published in either *The New England Journal of Medicine* or Britain's *Lancet*—two of the world's most respected medical journals.

Recent epidemiological studies also indicate these same occupational groups are the focus of an increased incidence of eye cancer and brain tumors. In addition, a heightened rate of congenital defects has been detected in the offspring of high-voltage power-substation workers.

In another population study, epidemiologist Nancy Wertheimer, of Boulder's University of Colorado, demonstrated an increased incidence of cancer among children whose homes have "high-current configurations" as defined by the particular type of electrical wires that run near the house. This finding has subsequently gained support from a Swedish health study. Meanwhile, Wertheimer has gone on to survey adults liv-

ing in the same "high current" homes. She finds that they too suffer from an increased incidence of some types of cancer.

As for the health impact of radar, TV, and radio waves, we are virtually in the dark. Epidemiological investigations of people living near TV and radio towers are almost nonexistent, and radar studies have been thwarted because of lack of data on those exposed to radar. As far back as 1962, a preliminary investigation by Charles Susskind, of the University of California at Berkeley, uncovered a possible link between leukemia and radar exposure. But the Department of Defense failed to provide funding for a more in-depth study. Almost a decade later, Dr. Peter Peacock, now in private practice in Fayette, Alabama, was "stonewalled" by the military when he discovered that a large number of clubfooted children were born to helicopter pilots. He suspected radar might be the cause, but he needed to perform further investigations.

"I even got a substantial grant from the EPA," Peacock says, "but the army refused to turn over any more medical records to follow up on this preliminary finding. Unfortunately, neither the National Institutes of Health nor a senator who got on the case could overcome the resistance of the military. After battling the red tape for over a year, we finally gave up. To my knowledge this area still remains virgin soil."

So what does all this mean? Unfortunately, nothing very conclusive. The problem is that almost all the epidemiological studies cited above are flawed. Take Peacock's suggestive finding. While the Navy's Tyler admits that the Army looks bad for not cooperating, he explains: "Peacock was getting his data from the reports of a pediatrician who diagnosed cases of clubfoot all over the place. You see, children are often born with their feet all twisted up because of their position in the womb. This condition can be mistaken for clubfoot, but it always disappears as the children mature. Once they got rid of this pediatrician, that correlation between helicopter pilots and children with birth defects disappeared."

Regarding Wertheimer's link between cancer and people living in houses with high-current levels, Tyler says, "At a recent conference at Battelle Northwestern, in Washington, several investigators reported that the size of the wire near the home is no indication of the type of radiation the occupants inside are exposed to. It also depends on other factors, including the types of appliances you have. So the whole basis on which she calculated high-power configurations simply does not hold up."

EPA's Tell is equally circumspect. "We certainly are seeing these kinds of reports with increasing frequency, which is kind of alarming. Yet all we can do is view them as a cautionary flag. It may look very convincing that electrical workers are coming down with cancer, but none of these investigations have paid sufficient attention to other causative factors, such as whether there are toxic chemicals in the workplace."

Criticisms of this kind rile Dr. Becker. "Sure, it's easy to pick flaws in individual studies. Because there's been practically no funding for epidemiological investigations, the researchers that did them have invariably been operating on a shoestring. Still, if you look at the strength of the findings as a whole across the world literature, I think any rational individual would have to conclude that we've got one hell of a problem."

Microwave News editor Slesin is also chagrined by the lack of funding. "Every study that has been done to date has been blunted by lack of sufficient funds to do it properly or by the inability to get all the data on a specific population," he says. "I think it is extraordinary that the government has never funded a major epidemiological study. This is a major, serious omission."

The most controversial explanation for this "major, serious omission" was advanced by Paul Brodeur in his 1976 best-selling book *The Zapping of America*. Brodeur theorizes that the military-industrial complex set out to suppress and distort knowledge in this area because the health implications it raised often conflicted with national defense interests and the expansion of technology. This is a radical position. Yet he and many scientists can cite examples of questionable conduct on the part of the military and its supposed corporate allies—in particular, the power companies and the manufacturers of microwave ovens and radar.

To science historian Nicholas Steneck, the conspiracy theory has been greatly exaggerated. In his newly published book *The Microwave Debate*, he emphasizes that microwave appliances emerged during the progress-oriented Fifties, long before Three Mile Island and Love Canal had dampened American enthusiasm for new technologies. In such an uncritical atmosphere, the standard setters did not always go about their task as cautiously as the public would now expect. As to the blind acceptance of the thermal model, which states that only levels high enough to cause heat damage are harmful, Steneck notes that "old doctrines die hard." With no adequate scientific explanation for low-intensity biological effects, he points out, it's easy to dismiss such findings as spurious experimental results.

Even so, Steneck acknowledges that two thirds of all support for research on the biological effects of microwaves and radio waves comes from the military, "which cannot be viewed as a disinterested party when it comes to making decisions about development versus health." Consequently, he advocates that funds for this kind of work be shifted to agencies that do not have user conflicts.

Wherever the truth lies, groups with a vested interest in the use of electromagnetic technologies are proving to be a formidable force in shaping public-health policies. State laws aimed at establishing health and safety standards for the use of VDTs are being vigorously opposed by such powerful lobbying groups as the American Newspaper Publishers Association, the American Insurance Association, the American Bankers Association, the American Electronics Association, the Air Transport Association of America, the Printing Industries of America, and the Computer and Business Equipment Manufacturers Association (CBEMA), which represents 42 of the largest computer and business-equipment makers in the United States.

The November/December issue of *The Columbia Journalism Review* reports that these groups have now joined forces, forming the Coalition for Workplace Technology, to counter the press's alleged misinformation on VDT hazards. CBEMA, which directs the coalition's lobbying activities, is sponsoring a multimillion-dollar education program to "explain clearly and concisely that there is no health and safety danger [from terminals]." Or as CBEMA Director of Communications Charlotte LeGates told *The Wall Street Journal:* Protecting pregnant workers from VDTs "is like protecting them from light bulbs. It's like employees saying, 'The office is filled with cosmic rays, and we need to fight them with balloons.' "

"American health advisers set tolerance levels for microwave exposure at 10 milliwatts per centimeter—a power density 1,000 times greater than what the Russians consider safe."

Another group concerned about public "fear and misunderstanding surrounding nonionizing radiation" is the Electromagnetic Energy Policy Alliance (EEPA), which is supported by the National Association of Broadcasters, the Association of Home Appliance Manufacturers, Raytheon, and AT&T. EEPA may well be a major opponent to a proposal the EPA is considering—one that would limit the emissions of radio and TV transmitting towers to levels ten times lower than those stipulated by the voluntary guidelines now in place. Possible human health risks—notably disorders of the nervous and immune systems—were the reasons cited for the novel proposal, first announced in June of last year. But so far, the EPA has not acted on the recommendations of its own study group.

Despite reassurances from CBEMA and EEPA, we can only guess at the scope and severity of health risks that may be posed by nonionizing radiation. Apart from the failure to conduct well-funded epidemiology studies, basic research in this area has barely crept forward, with investigators under constant fire for challenging accepted ideas. According to psychobiologist Rochelle Medici, who stood at the vanguard of brain EMF studies in the early Seventies, "It is as though scientists had retreated from doing challenging, frontier studies because such research engendered too much controversy or elicited too much criticism."

The upshot of all this: We now lack the scientific framework needed to make sense of the diverse range of EMF health effects being reported in ever-increasing numbers. How, for example, are we to interpret some of the distinct trends emerging in the literature? Why is it that different types of radiation—from high-frequency radar to low-frequency VDT emissions—are continually linked to cancer and other kinds of genetic/growth abnormalities? Could there be some common factor at work?

In the opinion of Becker, there is. And as might be expected, he turns to the papers of his Russian colleagues for the answer. According to Soviet scientists, living organisms evolved under the influence of the earth's geomagnetic field and are extremely sensitive to it. The orientation of the field, they believe, guides animals as they navigate through unfamiliar territory. And the Soviets think that the earth's daily fluctuations in strength—what geologists refer to as the earth's micropulsations—serve as a timepiece that regulates such fundamental body rhythms as the rate at which DNA replicates within cells. So from their perspective, it's only logical that radar, radio waves, and other contaminants of the natural magnetic field should disrupt everything from behavior to health. And if electromagnetic smog continues to rise, the Russians fear it could have the cataclysmic impact of a geomagnetic field reversal: Every few hundred thousand years (on average), the South and North Poles change position—a process that takes about 5,000 years and is supposed to coincide with massive extinctions.

Why aren't Western scientists concerned? Is it because our own findings are incompatible with the Russians' theories?

Consider Delgado's discoveries, for example. Perhaps his weak pulses of energy subtly change the effect the earth's own geomagnetic field has on animals, whose circadian rhythms responded accordingly. Could that be why monkeys became more sleepy or aroused, bacteria grew more slowly, and fish suddenly became pacified?

Delgado does not rule out these possibilities. "I am familiar with what the Russians think," he says. "And I believe the postulated role of the earth's geomagnetic field on life is very attractive. It may well turn out to be an important factor in evolution."

As a closer look at the Western literature soon revealed, there is growing evidence to support many of the Russians' notions: Bacteria, salamanders, bees, pigeons, whales, and tuna are just some of the species that have been shown during the last decade to use geomagnetic cues during navigation. And as early as the Sixties, magnetic fields as weak as the earth's were found to change the biological rhythms of primitive organ-

isms. These experiments, done by the late Frank Brown, of Northwestern University, in Evanston, Illinois, were initially subjected to ridicule. But in time, other scientists confirmed and built on his findings.

Rutgar Wever, in West Germany, for example, demonstrated that humans in habitats that shielded them from all Earth fields developed abnormal circadian rhythms. Furthermore, their body rhythms could be restored to normal simply by introducing a signal into their environment—one that oscillated at the average frequency of the earth's micropulsations. Another West German scientist, Peter Semm, has shown that the brain's pineal gland—the master gland that controls the body's biological rhythms—is sensitive to magnetic fields of the same strengths as the earth's. More recently, Klaus-Peter Ossenkopp, of Canada's University of Western Ontario, found that a biological rhythm related to opiate levels in the brain can be altered by magnetic fields similar to the earth's micropulsations or by naturally occurring magnetic storms.

Finally, James D. Hays, of Columbia University, in New York, discovered that the extinction of six out of eight species of a tiny marine organism called radiolaria coincided with geomagnetic field reversals, which he notes is "quite a surprising correlation." While he acknowledges that other factors could have contributed to the extinctions, Hays says, "My own preference is that the organisms are in some way using the field. In other words, the field matters to them."

Becker, for one, has little doubt that the field is significant. "All the evidence points very clearly to the fact that animals must intercept a normal magnetic field in order to maintain the functional integrity of their central nervous systems. We derive crucial information from that field—information that influences biorhythms, the electrical and chemical properties of the brain, and the growth rate of the organism as a whole. So you can't help but think, 'Hey, what is all that electromagnetic energy for communication and power doing to us?' What is the impact of that rising sea of radiation that has existed only for fifty of the 3.4 billion years that life has been around on this planet?"

Becker chomps down on his pipe before going on to paint an extraordinarily bleak picture of our future. "It should be obvious by now that abnormal fields cause acute physiological stress, a major predisposing factor toward disease. So if we continue to fill the airwaves with endless new frequency broadcast channels, we can look forward to increased incidence of cancer, birth defects, central nervous system abnormalities, and maybe"—he pauses for a deep breath—"the extinction of life."

After acid rain, toxic waste dumps, and fallout from nuclear reactors, who wants to worry about being zapped into oblivion? Could this be why Becker's message isn't getting through? Or is he just another alarmist, a soothsayer spouting a lot of negative hype? Few American scientists, even those deeply concerned about EMF health hazards, would take such an extreme view of the risks. It is probably fair to say that scientists familiar with the literature may be having second thoughts about the wisdom of building houses close to high-voltage power lines, or satellite-linkup facilities on the roofs of inhabited buildings, or VDTs that are not properly shielded. But few would advocate—as Becker has proposed—a moratorium on all new-frequency broadcast channels. And fewer still would raise the specter of extinction from EMF pollution.

Yet the Russians appear to share many of his fears. Despite the low esteem with which their science is regarded in the West, the Soviets have the world's largest research effort under way in bioelectromagnetism. And according to Americans invited over by the Soviet Academy of Science, this discipline has attracted some of the finest minds from the Russian space program.

"Sure the Russians take this very seriously," says Becker, adding out of the corner of his mouth, "at least when it comes to their own population."

Becker chomps down on his pipe again. "You don't think their monumental research program is aimed at purely humanitarian goals, do you?" he asks. "Or that it's any accident that some of their papers omit important details here and there?"

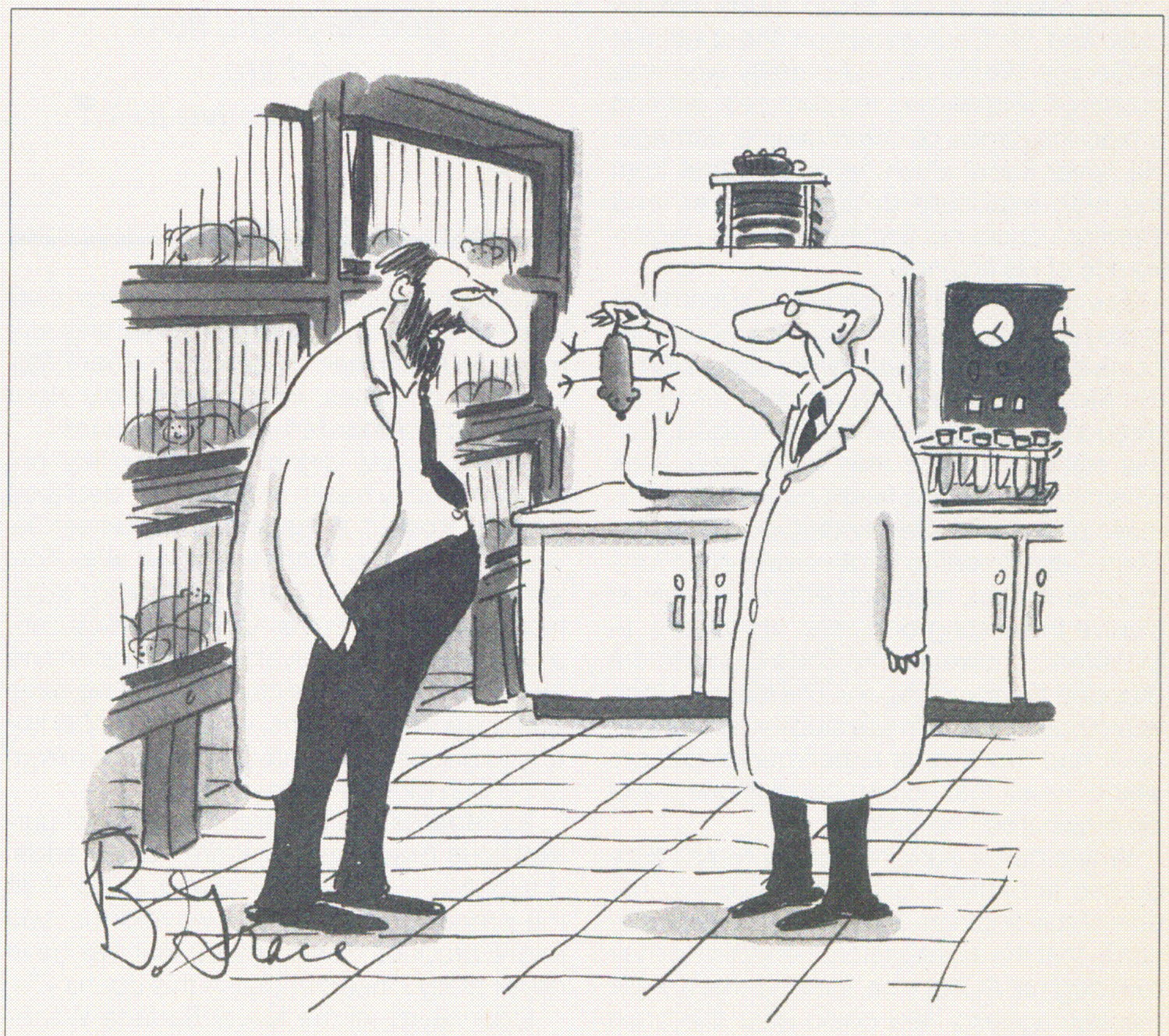
There was strange—and rather frightening—logic to some of his reasoning. After all, if energy we can't see, feel, smell, or taste can wreak havoc with our immune systems and even upset brain chemistry, it would seem to be the ideal weapon. But could this really have escaped the attention of the military, the staunchest defenders of the thermal model for safe EMF exposure?

"Maybe when they were setting the standards back in the Fifties," Becker says. "But you can be sure the Pentagon woke up to its potential as a weapon when the Russians started beaming weak microwaves at the American embassy in Moscow, and three ambassadors came down with cancer."

Have weak electromagnetic fields become a secret addition to the arsenal of modern warfare? If so, have health issues become somewhat clouded by military considerations?

Almost a decade has passed since U.S. embassy personnel were first informed that they were the target of a covert microwave beam. Yet the American government has still not disclosed the motivation for the Moscow signal, which has been directed—on and off—at the ambassador's suite and adjoining offices for more than 30 years. (According to a brief announcement in *The New York Times*, beaming was resumed for three months in 1983.)

Through the Freedom of Information Act, some documents on the issue have been made available. But even these have been heavily sanitized in order to guard national security. This veil of secrecy has naturally spawned rumors, and Becker is not the first scientist to claim that health impairment or



"A remarkable vaccine, Professor Steinmetz. But bear in mind that hamsters very seldom catch Dutch elm disease."

mind control could be the purpose of the Moscow signal. The State Department itself investigated—and subsequently dismissed—this theory. Or at least that is the official account.

From the start the extremely low power and irregular frequencies of the Moscow signal effectively ruled out the possibility that it was being used for jamming or for activating eavesdropping devices on the premises. Consequently, the intelligence community took little notice of the beam in the Fifties. It was not until the mid-Sixties that a command came down—apparently from the highest echelons of government—to investigate its biological impact.

So on the one hand, the government was telling the public that microwave exposure posed no danger at weak intensities. On the other, it was privately conducting studies to test these assertions since, as one intelligence memo from that period states, "There exists very little data in the United States or other Western countries on the effect of low-level microwave radiation."

Beginning in 1965, an investigation was launched along two main fronts. Unknown to embassy personnel, blood samples obtained from them during "routine medical checkups" were being scrutinized for signs of genetic damage. At the same time, the government began plans for a top-secret project, given the ominous code name Pandora, that would expose primates to microwaves similar to the Moscow signal.

The results of the blood study remain classified. Dr. Cecil Jacobson, the specialist at George Washington University who was in charge of analyzing the samples, did find a high incidence of chromosome damage. He never knew which samples came from the high-exposure group, however, and therefore could not test the statistical significance of his findings.

The outcome of the primate experiments is also unclear. After ten days of around-the-clock exposure to a laboratory simulation of the Moscow signal, one monkey fell into a deep stupor and could not be roused from this state until more than three days later, when the power was finally cut off. This dramatic and unexpected finding propelled the State Department to begin preparation for a more ambitious research effort that was to involve the testing of human volunteers. In midstream, however, the State Department dropped this line of inquiry. The reason: Upon examination, the primate study was found to have had flaws in its experimental design, which meant that no firm conclusions could be drawn from the data.

Why a better designed study wasn't conducted is baffling, given the shocking nature of the findings. One possible explanation is that the investigators fell victim to their own dogma. At that time, the idea that a weak electromagnetic field could alter the brain was tantamount to heresy. Once shortcomings in the experiment became apparent, there must have been a strong temptation to discount the findings altogether.

Not everyone accepts this explanation, however. A popular countertheory is that the government attempted to cover up health effects at low intensities because, among other things, a lot of expensive radar sets would have to be redesigned.

This kind of speculation only added to the worries of U.S. embassy staff members in Moscow when they were finally enlightened in 1976 to their role as unwitting guinea pigs. To appease them, the State Department was obliged to deem Moscow an unhealthy work post and provide 20 percent salary increases as compensation. In addition, aluminum shielding was nailed to the side of the building, and a massive epidemiological survey of the staff was launched.

This study, like many epidemiological investigations before and after it, was thwarted due to lack of data on the exposure levels of those surveyed. Neither the CIA nor the Department of Defense was keen on revealing any information on their personnel. Nonetheless, the results offered some reassurance to embassy employees. In 1978 the investigators concluded that the Moscow staff was not dying any faster or contracting any more diseases than diplomats in other Eastern Bloc countries, who presumably were not being bombarded with microwaves.

"According to Soviet scientists, living organisms evolve under the influence of the earth's geomagnetic field and are extremely sensitive to it."

"The Moscow signal was definitely not used to modify health or behavior," declares Samuel Koslov, a leading government investigator of the embassy affair who now serves as assistant to the director for technical assessment in the Applied Physics Lab, at Johns Hopkins University. "No one knows for certain what it was used for. But we have pretty good suspicions, which I'm not at liberty to discuss. They have nothing, however, to do with biology or psychology."

As regards the general feasibility of surreptitious brain manipulation, Koslov adds, "I suppose the possibility always exists. With the proper combination of waveforms, you might produce some effect. But we have never really looked at that in this country."

Eldon Byrd, of the Naval Surface Weapons Center, in Silver Spring, Maryland, disagrees. Between January 1981 and September 1982, the Navy commissioned Byrd to investigate the potential for developing electromagnetic devices that could be used as nonlethal weapons by the Marine Corps for the purpose of "riot control, hostage removal, embassy and ship security, clandestine operations, and so on." According to Byrd, the use of weak fields for the remote manipulation of the mind is feasible and was one of the possibilities explored. It should be noted, however, that this project was neither well funded nor continued past 1982. Unless a top-secret program is under way, such research would appear to be of low priority to the military.

"I don't think most people in government perceive that there could be a threat in this area," says the Navy's Paul Tyler. "But if you can create good effects, it stands to reason that you can probably produce bad effects. And there's no reason why this couldn't be done covertly. After all, we are not aware of the natural fields in the environment that control our circadian rhythms. Probably many things that can be done chemically could also be done electrically. With the right electromagnetic field, for example, you might be able to produce the same effects as psychoactive drugs."

A Russian machine called the Lida appears to do just that. A huge console built with World War II technology, it generates pulsed radio frequencies in conjunction with other sensory stimuli that are supposed to induce deep sleep. According to Adey, the only investigator in the United States to test the device, "Instead of taking a Valium when you want to relax yourself, it looks as though a similar result could be achieved with a radio field." In a recent interview, Adey declined to speak about the military applications of the technology. But at an earlier conference, he was quoted as saying, "Some people theorize that the Soviets may be using an advanced version of the machine clandestinely to seek a change in behaviors in the United States through signals beamed from the USSR."

To Delgado, this is nothing short of science fiction. "I don't believe it," he says. "The strength of electromagnetic fields falls so drastically with distance from the transmitter that it would be practically impossible."

Rather than worrying about unlikely scenarios, Delgado prefers to focus on the much more real risk posed by the growing contamination of the electromagnetic environment. In his opinion, there is an urgent need to conduct research that will help establish tolerable doses and to organize preventive medicine. He also emphasizes the importance of major programs for pursuing the *therapeutic* uses of EMFs, which "could lead to new treatments for conditions now considered hopeless."

But like many other scientists who have been lured into this once disreputable field, José Delgado is most eager to find the answers to questions that strike at the very core of life: "How do natural and artificial fields affect our behavior? What are the effects of the magnetic storms of the sun and the constellations? Is there an electromagnetic force driving our thoughts, our behavior, and finally, our lives?" ∞