Chapter 1: Beginning*

Awareness of possible health hazards from human-made electromagnetic energy in the environment emerges in a medical research laboratory; requisite gold-standard animal studies begin; the issue of justifiability arises. 1959–1974.

During the 1960s and 1970s Robert O. Becker, MD was the chief of orthopedic surgery at the Veterans Administration hospital in Syracuse, New York, and director of a research laboratory devoted to the study of what he regarded as central problems in human biology—the physiological role of the natural electromagnetic energy present inside humans and animals, and the effects on them due to externally applied man-made electromagnetic energy.

In medical school he had developed a keen interest in how the human body healed itself, and questions about the process arose in his mind. Where and in what form was the code for the healing plan stored, and what insured that the new tissue would be anatomically appropriate? Questions pertinent to this level of biological organization were not discussed by his professors or in his medical texts, which concentrated on biochemistry—DNA, RNA, genes, proteins, drugs—and paid scant attention to what controlled and guided biochemical reactions so that healing occurred and then stopped when the process was complete. He believed that knowledge of the control processes could benefit man- kind where normal healing was delayed or did not occur, outcomes he conceptualized as failures in the regulatory process that might be overcome if the governing biological laws were understood. Becker regarded even the apparent permanence of lost limbs and failed organs to regenerate as instances that might be treated successfully if the laws of growth control were discovered, a perspective that differed from the prevailing view that regeneration of limbs and organs by humans was beyond the limits of what medicine could accomplish.

By the end of his medical studies Becker had decided that a potentially useful line of inquiry beyond biochemistry had been overlooked. Inspired by cybernetic theorists like John von Neumann, he reasoned there must exist some kind of organized, purposeful physical force that controlled the behavior of biochemicals and brought about the marvelous result known as healing. When he came across the work of the Nobel-prize winner Albert Szent-Gyorgi dealing with the relation between electromagnetic energy and biology, Becker realized that electromagnetic energy was the only scientifically acceptable candidate as a supra-chemical-controlling agency of the healing process, and he decided to devote his life to clinically relevant research aimed at pursuing his ideas. Immediately after finishing his orthopedic residency he took a job at the Veterans Administration (VA) hospital in Syracuse specifically because he was promised the

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opportunity to do the kind of research that interested him.

Guided by an instinct that natural electromagnetic energy in the body was the key to understanding growth control, Becker did experiments and was immediately successful, at least in terms of how academic success was measured in those days. Beginning in the early 1960s, he published many peer-reviewed papers in biology, medicine, and bio- engineering journals that provided experimental evidence of an unrecognized growth- control system in the body that operated by means of the flow of natural electromagnetic energy. His results showed that the control system somehow resided in the central and peripheral nervous systems but was distinct from the digital electromagnetic energy system that facilitated sensory perception. Then he went further and published results that implied the novel control system could be affected by changes in the geomagnetic field, thereby identifying the internal electromagnetic energy system as a link between humans and the environment.

In the fall of 1964, I began my second year in a physics PhD program at Syracuse University and was expected to choose a field of specialization. But the traditional options—particle physics, nuclear physics, relativity, solid-state physics—did not interest me. I heard about Becker's laboratory in the VA hospital, which was across the street from the University campus and faced the law school. He interviewed me for a position in his laboratory even though I knew nothing about biology or medicine, and told me what he did, and why. I saw immediately what I thought was greatness in his ideas, and when he asked, "Do you want the job?" I accepted even before the air molecules that carried "job" to my ears had stopped vibrating.

In his laboratory I studied the biophysical properties of bone and tendon, using the same methods that physicists used to study any material. I obtained bone from the operating room, dried it, treated it with acetone to remove the fat, cut it into cubes, and made measurements of its dielectric constant, electrical conductivity, piezoelectric constant, and electron resonance properties. I did not understand how my results fit into Becker's theories, but he seemed satisfied and that was enough for me. Mostly I was concerned that my work was suitable PhD-level research, and that consideration guided my choice of experiments.

When I got my PhD in 1968, Becker asked me to continue working in his laboratory. That same year a stone quarry near my house began creating high levels of noise and dust, and detonating explosions that were so violent they would knock my son out of his crib. After I complained, a hearing was held to determine if the activities at the quarry were hazardous. At the hearing the company's lawyers presented expert witnesses who testified that the sound levels on my property were like the chirping of the birds, the quarry produced no dust, the vibrations from explosions were undetectable beyond the com- pany's property and that methods used for mining and crushing the stone were generally accepted as completely safe. I tried to challenge that bullshit but

the judge said that only he had the right to ask questions and he saw no reason to do so. Three months later I entered law school. During each semester for the next four years Becker arranged my official work schedule in the laboratory so I could attend law classes.

Becker allowed me to design my own experiments and I produced many publications involving the electrical properties of bone and tendon, but I progressively developed doubts regarding whether such knowledge was useful. Meanwhile, Becker followed his lines of inquiry into the role of natural electromagnetic energy and the identification of principles and mechanisms that the body used to control growth and healing. As early as 1962 he had shown that applying man-made electromagnetic energy could make bone grow, the first time that control over a specific growth process had been achieved by human intervention. He moved slowly toward bringing his discovery into clinical use because of his concern about the side-effects of applied electromagnetic energy, which were unstudied.

Others who followed the bioelectrical path Becker blazed were less reticent. An orthopedist at Columbia and another at the University of Pennsylvania were far ahead of Becker in terms of industry connections; their work resulted in patents that were assigned to their sponsors: a mining company for one and the U.S. Navy for the other. The patients of both doctors consented to receiving treatment of electromagnetic energy, but Becker wondered about the quality of that consent because he knew that patients would accept almost any recommendation made by their doctors. He also knew that neither orthopedist shared his conviction that electromagnetic regulation was a fundamental determinant of human physiology; “If you take it away, you take away the thing we recognize as life,” he once said to me. From his perspective, the clinical attempts to tap into the natural biological control system needed to be done with greater care, and only after more animal research had been done.

Another aspect of Becker’s research, one that gave rise to my life’s work, including this book, involved the effect of man-made electromagnetic energy in the human environment. In 1967 Becker received a letter from a Florida congressman named Paul Rogers who said he was sponsoring a bill in congress dealing with radiological safety of devices that emitted man-made electromagnetic energy into the human environment. His bill would require manufacturers to show that their devices would be safe before they could legally be sold. The pre-market approval step was to apply to any form of man-made electromagnetic energy over which the federal government had jurisdiction, whether X-rays, light, microwave ovens, or communications signals. Becker supported Rogers’ bill but the version that ultimately became law imposed no pre-market regulations on manufactured devices that emitted man-made electromagnetic energy into the human environment. In 1972, in a talk at the annual convention of a national association of engineers, based on considerations regarding the body’s cybernetic control system, Becker warned against “the continuous exposure of the entire North American

population to an electromagnetic environment in which is present the possibility of inducing currents or voltages comparable with those now known to exist in biological control systems." Soon after that talk, he asked me to put aside my biophysical studies of bone and tendon and concentrate on experiments that could help determine whether man-made electromagnetic energy was safe.

I had no clear idea about how to go about determining the safety of man-made electromagnetic energy, but I had studied Environmental Law and happened to be studying Health Law that semester, and it occurred to me that the principles followed in those areas ought to apply to the task Becker had given me. I pursued that hunch and discovered the idea of a "gold-standard study."

My enlightenment began after I noticed a disclosure on a box of breakfast cereal that "product freshness" had been preserved using a chemical additive called "BHT." I wrote the manufacturer to ask how they knew BHT was safe and was told that they had studied its effects on laboratory rats. An official at the Food and Drug Administration told me that such studies, those with an experimental and control group where the resulting data was evaluated statistically with respect to a determination of cause-effect, were the "gold-standard" for assessing the safety of food additives. I soon learned that federal laws governing the licensing of pesticides and herbicides also required gold-standard studies. A pesticide manufacturer, for example, was required to produce laboratory evidence that a proposed new pesticide was safe for humans. The requisite evidence of safe- ty consisted of gold-standard studies at different dose levels of the pesticide until the no- effect dose level was found. A safety factor of a hundred was then employed and the pesticide was legally characterized as "generally regarded as safe for humans" at doses no greater than a hundred times below the "no-effects" level. The regulations for insuring safety of drugs were even more stringent. Gold-standard studies had to be done on animals to prove safety and on patients to prove that the drug was effective for treating their disease. The regulations in all these areas were clear about what kind of scientific evidence was needed, and what the reasoning process was that connected the scientific data to the conclusion of "completely safe."

Following the logic of the federal rules and regulations governing the safety of chemicals, food additives, and drugs, I began gold-standard animal experiments on the biological effects of man-made electromagnetic energy. I intended to interpret any biological effects I found as evidence that the energy was at least potentially unsafe because it affected the metabolism of the body, which was something that was not supposed to happen. During the next year I found many different kinds of effects in mice and rats, which Becker interpreted to mean that the electromagnetic energy I applied had perturbed the natural regulatory systems in the animals, thus confirming his concerns about the health risks of ever-increasing levels of man-made electromagnetic energy in the human environment and his opinion that more animal studies were needed.

I developed a somewhat different viewpoint regarding the meaning of my

results—that they were what they were irrespective of whether or not the energy directly affected natural regulatory systems in the body which, by this time, I had come to conclude with metaphysical certainty must exist and must be crucially important in the de- termination of health and disease. I drew the implication of a health risk from the existence of the effects, not from the nature of the process or mechanism that mediated them. Assuming that other investigators also found effects in animals due to comparable levels of electromagnetic energy, I believed that the existence of energy-induced bioeffects re- quired some basic steps to warn and/or protect the public health because the law would presume that they were adverse to health.

I didn't dwell much on the specific energy-induced effects that were observed. For one thing, the effects I looked for in relationship to energy exposure were not effects I specifically predicted, but were effects I could conveniently measure because I had the necessary laboratory instruments. Had I been doing the experiments to pursue a particular scientific theory, the rule would have been for me to predict a specific effect that was expected based on the theory. But I wasn't doing that kind of research. I wasn't testing a particular theory but rather was doing something less intellectually exciting but far more important for ordinary people: I was looking for evidence of unsafety, which was the condition that the civil law regulated. I thought that the existence of reliable biological effects in animals would be sufficient to warrant health concerns and steps to warn people who might be inadvertently exposed to the man-made electromagnetic energy.

While I was performing my experiments with mice and rats, the Navy began Project Sanguine, an effort to plan and build a huge antenna in Michigan. To meet the requirements of federal law, which required objective assessment of the environmental impact of new construction, the Navy funded animal studies to permit evaluation of the antenna's electromagnetic energy. Becker served on a Navy committee to evaluate the interim results of the studies, and at a meeting of the committee he learned about many energy-induced biological effects that occurred in various human and animal experiments, including several effects that were similar to those in our animal experiments. He also learned that the type of electromagnetic energy from the Sanguine antenna was similar to the energy from powerlines, although much weaker. A few weeks after returning home from the meeting, he read in a newspaper that power companies in New York intended to build two of the world's largest high-voltage powerlines. He immediately wrote to responsible state officials, "I wish to call to your attention certain serious human health and general ecological problems that might be associated with the proposed powerlines." His point was that the Navy's gold-standard studies as well as our studies had shown biological effects, and that whatever the risks might be they would surely be much greater in the case of the powerlines because the energy from powerlines was more than a million times greater than that from the proposed Navy antenna.

In response to Becker's letter, a young lawyer named Robert Simpson who worked for the Public Service Commission, the state agency charged with

representing the public interest regarding all aspects of powerline construction and safety, visited Becker and told him that a power-company expert had testified that the energy from the proposed powerlines would be "completely safe." Becker asked Simpson what basis the expert had for his opinion and Simpson replied, "he said he saw cows standing under powerlines, wagging their tails, which indicated they were contented." Surprised and dis- concerted, Becker agreed to testify as an expert witness and he volunteered me as a wit- ness. Simpson knew I had just finished law school, and asked Becker that I also be al- lowed to assist with cross-examination of the company experts. As a public service, the appropriate VA officials granted Becker and me permission to participate in the hearing as long as we made it clear that our opinions were our own and not necessarily those of the VA.

WORKING WITH SIMPSON, Becker wrote a statement in the required question-and-answer format that expressed his opinions about energy-related health risks and their biomedical basis, and he explained why he thought the Commission should evaluate the situation before approving the powerlines. In pertinent part he wrote:

Q. What have you been experimenting on, and for how long?

A. For the past 15 years we have been studying the effects on animals caused by a variety of different kinds of electromagnetic energy.

Q. How do these effects come about?

A. The basic reason is that the body has an electrical system which controls growth and healing, and is probably related to the perception of pain. There is evidence that the system also links biological cycles of behavior exhibited by humans and animals to the cyclic patterns of environmental electromagnetic energy that occur in nature. The physical properties of the cells of this electrical control system are such that it would be influenced by changes in the level of electromagnetic energy in the environment.

Q. Could effects occur in response to the electromagnetic energy from the proposed powerlines?

A. The strength of those energy levels and the duration of exposure to them are both far beyond the levels and durations that result from any other source of electromagnetic energy man has ever built. Consequently the proposed powerlines pose the highest risk of biological effects.

Q. What is the medical significance of your conclusion?

A. From a medical viewpoint, our work and that of many others described in the literature represents a solid body of data indicating that living organisms are influenced by electromagnetic energy, and that such effects are likely to occur in the areas of growth, both cellular and of the total organism, and in the function of the central nervous system and cardiovascular system. The effects could occur directly, as when the energy interacts with a particular tissue and causes it to change from healthy to

diseased tissue, or they could occur indirectly, as for example a stress response. Obviously, to answer particular questions such as the specific effects of different durations of exposure to various strengths of electromagnetic energy upon the health of the variable human population will require specific laboratory experimentation. These answers are not available at this time.

Q. Do you believe that the proposed powerlines would be safe if they were built as presently designed?

A. No, for the reason that its electromagnetic energy level will be in the range possibly productive of biological effects. I believe that chronic exposure of humans to such levels should be viewed as human experimentation, and subjected to the rules previously mentioned. I believe that the most prudent course to follow would be to determine the complete spectrum of biological effects produced by exposure to powerline energy. It should then be possible to establish firm levels of permitted exposure with regard to both the energy levels and the permissible duration of exposure.

MY TESTIMONY followed more or less automatically because I wrote it to support Becker. My objective was to put in evidence all the gold-standard studies that had been published, relate the level of man-made electromagnetic energy in each study to the distance from the centerline of the powerline where that level would occur in the human environment, and to indicate how much farther from the centerline a level that incorporated a safety factor of one hundred would occur. I cited forty studies, including two that Becker and I had done, and described each.

In humans, the energy altered reaction time, triglyceride levels, psychological performance, and biorhythms; in rats and mice it affected electroencephalograms, blood cells, growth rate, and enzyme levels. The energy produced a diverse range of alterations in chickens, brain cells, amoebae, birds, worms, slime mold, bees, dogs, and monkeys. Many of the studies were produced as part of Project Sanguine, a novel big-science pro- gram in the U.S., designed to evaluate the health risks of man-made electromagnetic energy.

Gold-standard studies of the biological effects of man-made electromagnetic energy

Investigator	Institution	Animal	Duration of Exposure
Altman	Univ. of Saarbrucken	Guinea pigs	13 days
Altman	Univ. of Saarbrucken	Mice	3 days
Bassett	Columbia Univ.	Dogs	28 days
Bassett	Columbia Univ.	Humans	3–6 months
Bawin	UCLA	Brain tissue	
Becker	VA Hospital Syracuse	Mice	20 minutes
Becker	VA Hospital Syracuse	Rats	6 months
Beischer	US Navy	Humans	1 month
Blanchi	Turin Univ.	Mice, rats	
Durfee	Univ. of Rhode Island	Cells	
Friedman	VA Hospital Syracuse	Humans	
Friend	US Navy	Amoebas	
Gann	Johns Hopkins	Cells	
Gann	Johns Hopkins	Dogs	

1 day
1000 hours

3 days

Several hours
10 minutes

7 days
5 hours

Several minutes

28 days

1 day

600 days

Several minutes
Several minutes

10 days
10 months

Several minutes
4 months

56 days

90 minutes

4 hours
5 days

Several minutes

28 days

10–150 days

1 month

40 minutes
Several hours
2 minutes Several minutes Several months Several days

9 days
8 weeks

In each study, the measurements had been made using standard laboratory methodology, and the error rate of the measurement was shown to be within the accepted range. The data obtained was analyzed using standard statistical methods, the possibility that the putative effect was due to chance was shown to less than 5%, and the final report had been subjected to peer-review. In most cases, the distance from the powerlines that the energy used in the study would occur was far beyond the proposed right-of-way. I concluded that the energy would likely cause biological effects in exposed people as it had in animals, but that I couldn't predict exactly what effect would occur in any particular person or how long the exposure would need to be to produce an effect. I recommended use of a safety factor when evaluating public safety, as was the routine practice when the safety of chemicals introduced into the environment was evaluated.

Simpson sent our testimonies to the power companies late in 1974 and it triggered a series of complex inter-related events. The companies withdrew the expert testimony they had submitted and requested a delay in the hearing until they could identify and hire new experts. Officials at the Commission, realizing that the legal interests of all power companies in New York could be impacted by the testimony Becker and I would give, invited all power companies in the state to participate as parties in the hearing. At the same time, the power industry's national organization, The Electric Power Research Institute began funding research projects with contract-research companies to perform animal studies on the effects of powerlines electromagnetic energy.

Investigators from one of the contract-research companies, Richard Phillips, a physiologist, and his engineering assistant William Kaune visited our laboratory and inspected our animal exposure facility. They told Becker and me that their objective was to repeat our experiments and prove our results were invalid. Kaune said he thought they arose from "inconspicuous experimental deficiencies." Phillips told me he would make all possible efforts to mute his criticism of my work when his results were eventually published because he recognized that I was "young and just getting started." He told me about a federal agency that also had money to spend for electromagnetic-energy bioef- fects research and suggested that it might provide me some funds "under the right circumstances," which I took to mean a willingness to diffuse the implications for his clients of the research results that Becker and I had obtained.

The identities of the expert witnesses hired by the power companies were disclosed in mid-1975. The most important expert was an engineering professor at the University of Pennsylvania named Herman Schwan, who was known for his opinions on health risks of microwaves. When I had begun planning my gold-standard experiments I contacted him concerning how he formed his opinions, but soon decided that the problem of health risks could not be reduced to strictly physical concepts, as he had done, and that gold-standard studies were essential. His involvement in the hearing was troubling be- cause of the political power wielded by the interests who presented him to the world as an expert on health risks of man-made electromagnetic energy.

Schwan received his PhD in biophysics from the University of Frankfurt in 1940 and worked there during the Second World War. His doctoral research and wartime publications involved the heating effect of microwave electromagnetic energy on tissues, a process called diathermy that was used by physical therapists. Two people who knew him during the war told me he had invented the microwave oven in 1943 for use on German submarines, but I found no direct support for the claim. I also didn't find any evidence Schwan was a Nazi, but Boris Rajewsky, Schwan's doctoral-research mentor and boss at Frankfort University before and during the war years, was a Nazi.

After the war ended, in response to a demand by the U.S. government that Schwan disclose the research he had done, he wrote a detailed report about microwave heating of muscle, which he disclosed had been a continuation of work begun by Rajewsky. Both men were persons of interest to U.S. officials for purposes of recruitment because of their expertise concerning electromagnetic energy. Rajewsky was disqualified from American citizenship because he had been an active Nazi, but Schwan was judged acceptable.

Schwan attracted the attention of the U.S. Navy, which had begun to confront the issue of health risks from the microwave electromagnetic energy used in radar and communications. The Navy sponsored Schwan's admission to the U.S and his application for citizenship, and it hired him as a researcher at the Philadelphia Navy Yard. Then he was hired as faculty at the University of Pennsylvania where his salary was paid by research contracts between the University and the Navy.

With funding from the Navy, Schwan published a series of articles containing explanations of how the electrical properties of materials determined the amount of heat that was deposited in them when they were exposed to microwaves. Then suddenly, in 1955, he announced that he had solved the Navy's problem of identifying the exact exposure level to microwaves that was safe for servicemen. The first step in his solution was to re-conceptualize a human as a geometrically simple, inert physical object. He said, "Assume a human being is an object shaped like a sphere made of muscle tissue." Next, he assumed that the so-called "hit theory" he had learned from Rajewsky, which ex- plained how X-rays affected matter, also applied to microwaves. When Schwan applied the hit theory to the sphere, the trivial result was that heat generation was the only physi- cal consequence caused by the microwaves. Schwan then reconceptualized the concept of "safety" to mean the absence of thermal effects. He asserted that ten milliwatts of microwaves, which caused a tiny increase in the temperature of the muscle sphere, was completely safe because the temperature increase it produced was less than that caused by exposure to the sun. Schwan argued that his calculated safe level should be adopted until incontrovertible empirical evidence of health injuries was produced.

Schwan had arrived in the U.S. at a particularly propitious time for him and the Navy. He wrote on a clean slate regarding health risks of microwaves because the question had never previously been considered, and he had overwhelming political and finan-

cial support from the military. All the winds were blowing in the right direction for him, and the military quickly adopted his claimed safety level even though neither he nor anyone else ever took even a single theoretical or experimental step toward validating the claim.

After the military adopted Schwan's safe level for its personnel, U.S. civilian agencies including the Federal Communications Commission, Federal Trade Commis- sion, and the Food and Drug Administration adopted it for civilians. In 1972 Schwan ar- bitrarily extended his reconceptualizations and use of hit theory from microwaves to low- frequency electromagnetic energy and concluded that Sanguine would be completely safe. Inasmuch as the Sanguine antenna operated essentially at the same frequency as high-voltage powerlines, I expected he would reason in a similar matter when he testified in the powerlines hearing, and he did.

In his direct testimony Schwan said:

Q. Could you outline your major areas of specialty?

A. I am a biophysicist. My major areas of specialty include: mechanisms of electricity conduction in tissues, cells, subcellular organelles, and biological molecules; ef- fects of electromagnetic energy on cells and biological molecules; effects of electromag- netic energy on biological systems in general and man in particular. The electromagnetic energy includes that from powerlines, radio and television antennas, and radar. I am aware of environmental health considerations that are under debate in these areas. I am concerned on the one hand to see man appropriately protected and on the other hand to provide protection at a reasonable and economically justifiable cost to society.

Q. What was the methodology utilized which permitted you to conclude with certainty that the electromagnetic energy from the proposed powerlines will be completely safe?

A. My theoretical analysis showed that the energy levels which will be caused inside exposed persons will be far too low to produce any biological effect whatsoever.

Q. It has been alleged there is potential for deleterious biological effects from powerlines fields. Do you agree with this statement?

A. No, I certainly do not agree. Extensive background and experience exists in the general field. It is reported that the attractive powers of lodestone were observed about 3000 BC. Written records mentioning the electrical properties of amber come from a Greek, Theophrastus, about 300 BC. In 1600, Gilbert, of England, deduced ideas concerning magnetic fields and polarity. Further, discovery and organization of this earlier knowledge into scientific principles took place substantially in the 1700s and 1800s by such scientists as Volta, Faraday, Ampere, Gauss, Galvani, Henry, Kelvin, and Maxwell. Muscle contraction of a frog under influence of electric discharges was demonstrated by Galvani. Maxwell developed his electromagnetic theory about 1870; these principles are

universally accepted today. These principles coupled with biological principles form a body of information that has been scientifically tested and proven. Based upon this in- formation we can predict that there will be no biological effects from the electromagnetic energy emitted by the proposed powerlines. Consequently, it is my firm conclusion that exposure to the proposed powerlines' electromagnetic energy will be completely safe.

Q. It has been claimed that effects of electromagnetic energy have been observed to take place at the system or organ level. Have you studied these claims, and if so, would you state your conclusions?

A. The support for the postulation of such effects is derived from studies which are either incomplete and/or of poor scientific quality. The studies claiming to have demonstrated the effects are characterized by a lack of proven cause-effect relationships and inconsistent experimental results. Additionally, there is no basis in the laws of phys- ics to substantiate the conclusion that such effects are harmful.

The second expert witness offered by the power companies to rebut Becker and me was Sol Michaelson, a veterinarian from the University of Rochester. I had met him when he visited the Syracuse VA with a team that was inspecting the hospital's animal research facility. He smiled easily and spoke softly, but the research he did was odious—exposing dogs to lethal doses of X-rays. He lamented what he called "the mystique about radiation death" and told me, "death by radiation is a quiet death, not violent like a heart attack."

Michaelson became a veterinarian in 1946 and worked for a relief agency, a university, and a drug company; in 1953 he began experimenting on dogs as part of the Atomic Energy Project at the University of Rochester. Michaelson met Schwan in 1957 and, under contract with the Navy, began studying the heating effects of microwaves on dogs. His publications contained gut-wrenching photos of dogs that died from micro- wave-induced heat stroke, strikingly similar to his earlier photos of dogs that died from radiation poisoning.

When Michaelson studied microwaves, the issue of health-risk evaluation was the domain of military planners but was rapidly becoming a concern of the companies that were on the cusp of a great increase in commercialization of man-made electromagnetic energy. He became deeply involved with commercial interests as an advisor, consultant, contractor, and expert witness, and he rocketed to national prominence. Michaelson was appointed to essentially every national and international expert panel involving man- made electromagnetic energy that was formed in the 1960s and 1970s, and he became an effective attack dog against the scattered few voices that opposed the interests of his cli- ents, most notably the ophthalmologist Milton Zaret and the physiologist Allan Frey.

In his direct testimony Michaelson said:

Q. Have you formed a professional opinion as to whether the levels of electromagnetic energy that will be produced at ground level by the proposed powerlines will be a risk to health and safety, and if so, what is that opinion?

A. Yes. It is my opinion that there will be no hazardous biological effects resulting from exposure to those levels.

Q. What is the effect of electromagnetic energy on animal tissues?

A. It produces a tiny amount of heat that is of no physiological consequence because the body can handle it; according to Dr. Schwan, it is impossible for the powerlines to produce enough heat to be hazardous.

Q. Is there a distinction between a biological effect and a hazardous effect?

A. The fact that a living organism responds to many stimuli is a part of the process of living. Such responses are examples of biological effects. Since biological organisms have considerable tolerance to change these effects may be well within the capabil- ity of the organism to maintain a normal equilibrium. If, on the other hand, the effect is of such an intense nature that it compromises the individual's ability to function properly or overcome the recovery capability of the individual, then the effect my be considered a hazard. Thus we must first ask if there are effects, and then if there are, we can ask if they are hazardous.

Q. Are there studies that demonstrate a lack of significant biological effect from the level of electromagnetic energy that we discussed?

A. There are many studies involving American electrical workers which were mostly negative and showed only a few inconsequential positive effects.

Q. Were the studies contradicted by the studies on electrical workers in the Sovi- et Union?

A. An inordinate significance has been attached to the Soviet studies. There are a number of scientific difficulties with those studies, not the least of which is that inadequate detail was provided in the studies. The work is subject to criticism because of limited statistical analysis of data, inadequate controls, and lack of quantification. Soviet publications typically lack descriptions of methods and controls, and often fail to provide results that can be scientifically evaluated by the reader. They employ an idiosyncratic vocabulary that mixes empirical observations with theory. The Soviet scientific literature must be read with caution. I have made an attempt to contact Soviet scientists, but they have been uncooperative. We must be skeptical of their work when their conclusions are contrary to well-documented, accepted work in the U.S. Soviet reports describe such symptoms as listlessness, excitability, headache, drowsiness, and fatigue in persons occupationally exposed to electromagnetic energy. These symptoms are caused by many other occupational factors so it is not possible to define a cause-and-effect relationship.

Q. Have there been studies to determine the biological effects of electromagnetic energy like that from the proposed powerlines?

A. Yes. Most of those are associated with Project Sanguine. One of the studies that has received much undeserved attention is the Beischer study. The only observed change in his subjects was an increase in serum triglycerides, and the importance read into this change is unwarranted. For example, of the 13 volunteers in the study, 3 were Navy corpsmen, while the other 10 were either commissioned officers dropped from the flight program or officer candidates who dropped out voluntarily or who were physically unqualified for flying. Suspiciously, the corpsmen were all in the control group; not one of them entered the exposed group. Another pertinent observation is that two of the exposed subjects had an argument during the study which resulted in a high state of arousal which was still present the following morning. This is significant because the arousal could have affected the triglyceride levels.

Q. Based upon all your work and analysis would you recommend that further studies be done prior to construction the powerlines?

A. No. I believe that sufficient scientific data are currently available upon which to make an accurate judgment concerning the health and safety of the proposed powerlines. There is no demonstrable biological effect which is hazardous to health or safety as a result of the presence of the electromagnetic energy from the proposed powerlines.

The third power-company expert witness was a botanist from the University of Rochester named Morton Miller. After receiving a PhD from the University of Chicago he worked at Brookhaven Laboratory and then joined the same department as Michaelson at the university of Rochester. Initially, Miller's research involved the effects of X-rays and ultrasound on plant cells; around 1971 he began studying the effects of Sanguine en- ergy on the roots of bean plants. Becker had learned of Miller's results during the meet- ing he attended on the potential hazards of Sanguine energy, and he described them to me dismissively because Miller was one of the few university researchers in the Sanguine project who found no effects. I met Miller after the power companies had hired him, when he visited our laboratory to inspect my animal-exposure apparatus, and he immediately struck me as half-witted. While standing in front of mouse cages he took out a 9-volt battery and touched the terminals to his tongue, jerking it away after each of three such demonstrations. "That's what happens to your mice," he said. I asked how he knew that and he said Schwan had told him.

In his direct testimony Miller said:

Q. Please describe your role in this case.

A. My role was to advise the power companies as to whether or not I believe there are potentially significant biological effects due to exposure to the electromagnetic ener-

gy from the proposed powerlines. Because of my personal involvement in the Project Sanguine program, I have focused my analysis on the biological research conducted in connection with this project.

Q. What methodology did you use in forming your opinion?

A. I examined the biological literature dealing with the effects of electromagnetic energy, and I also drew on my own research. In addition, I visited an operating powerline to assure myself that I had not overlooked any obvious potential effects on plants. As a trained observer, I was in a position to see any adverse effects on plants. I also consulted with Dr. Herman Schwan and Dr. Sol Michaelson. In this manner I was able to assure the completeness of my review as well as subject my analyses and conclusions to peer review.

Q. Please describe the Project Sanguine research that you reviewed.

A. I reviewed the research performed by the Hazelton Laboratories. It consisted of nine separate projects, all of which were largely negative or inconclusive. In addition, I was one of the scientists who conducted a study pertinent to Sanguine. I found that expo- sure of bean roots for six days to electromagnetic energy similar to that from the San- guine antenna did not affect growth of the roots.

Q. How would you summarize and interpret the completed Sanguine studies?

A. No consistent effects have been found. Hence the results of the studies indicate that there are no adverse health or safety effects to living organisms as a result of expo- sure to the electromagnetic energy.

Q. Have you formed a professional opinion regarding the safety of the proposed powerlines, and if so please state that opinion?

A. Yes. It is my opinion that the electromagnetic energy from the proposed powerlines does not pose an unreasonable risk to public health or safety.

The political process regarding the Navy's plan to build the Sanguine antenna continued during the powerline hearing. The original proposal was to build the antenna in Wisconsin, but the Secretary of Defense, who was from Wisconsin, changed the planned location to the Upper Peninsular of Michigan. When the health concerns expressed by the 1973 Sanguine committee that Becker served on became public, the residents of the Upper Peninsula protested and essentially every local community went on record opposing construction of the antenna. The Navy then asked Philip Handler, the president of the National Academy of Sciences to appoint a panel of unbiased experts to evaluate the safety of the antenna. Handler appointed sixteen men including Schwan, Michaelson, and Mil- ler, but not Becker.

The power companies were in business to make a profit, but the law required them to "furnish safe and reasonable service and facilities" and to make "all changes and

improvements necessary for the safety of its patrons, employees, and the public." So, the companies served dual interests, those of their stockholders and of the public, and had a fiduciary duty to both. But after reading the testimony of Schwan, Michaelson, and Miller I could not see how the companies were taking seriously their responsibility toward the public. Schwan, who did no research, said that risks were impossible according to the laws of physics. Michaelson, whose only research involved killing dogs horribly, had opined that energy-induced effects in animals when imputed to involuntarily exposed humans were acceptable until someone somehow proved to a scientific certainty that they were adverse. Miller, the half-wit botanist who studied bean plants, told the court there were no unreasonable risks, oblivious to the fact that the law does not permit power companies to create involuntary risks, whether reasonable or unreasonable.

I thought that the power companies needed to learn the lesson on the nature of a fiduciary duty that Justice Cardozo had taught in *Meinhard v. Salmon*, a New York case he decided in 1928. A broker was hired to sell a building. Through a dummy corporation, the broker himself made an offer of $80,000 and the client accepted. When the corporation resold the property a few weeks later for $87,500, the client suspected hanky-panky and sued. In his ruling, Cardozo pointed to an obvious conflict-of-interest: A broker's duty is to get the highest price, but a buyer's goal is the opposite. The broker claimed that he revealed enough information when he told his client that the corporation was also a client. Not good enough, said Cardozo, and he laid down the rule regarding disclosure that applies to anyone who owes divided fealty: "If dual interests are to be served, the disclosure to be effective must lay bare the truth, without ambiguity or reservation, in all its stark significance." I went about my business preparing to design the cross- examination of the company experts believing this rule applied to the power companies, and that the difficult problem of the safety of man-made electromagnetic energy could best be resolved if the companies respected Cardozo's dicta.