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SCIENTIFIC EVIDENCE AND PUBLIC DECISION MAKING

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A continuing stream of diverse new technologies, introduced for private profit or public benefit, characterizes our civilization. Stimulated by a growing list of unfortunate experiences, increasing attention is now being given to possible dysbenefits of these technologies, such as social disturbance or hazard to the public health. In consequence, risk assessment has become a major enterprise. Establishment of the nature and magnitude of the risk, if any, associated with a given technology is a valid scientific question. The acceptability of such risk, however, is a political question. The role of the scientist is to inform; decision is the responsibility of the polity, albeit frequently made by those to whom the polity has temporarily delegated that responsibility on its behalf.

The public is informed that automobile seat belts do save lives but each of us decides whether we wish to use them; less than 20 percent do. Evidence describing the linkages of cigarette smoking to lung cancer and cardiovascular disease is offered to the citizenry, which then decides, individually, whether or not to smoke. Those instances in which the public purpose can only be served by government action, e.g., licensing of nuclear power plants, approval of food additive or—the examplars in this article—construction of high voltage transmission lines or of antennae that emit extremely low frequency radiation, again entail a two-stage process, viz., scientific appraisal followed by political decision. While the formal separation of scientific information from public judgment is a truism, the two are not always easily distinguishable, they do not always operate independently of each other and their intertwining may have messy consequences in the making of public decisions. The unwary can be trapped and unprincipled advocates rewarded when the rules of either arena are not understood or their operation is inadvertently or deliberately distorted. The problem may be particularly serious when relevant, conflicting evidence derives not from the mainstream of scientific understanding but from a relatively little explored fringe and is offered by partisan scientists in the employ of an entity that benefits from the technology in question or by scientist-advocates already committed to the view that the technology is, in some way, dangerous or undesirable. It is then that the intricate structure and built-in safeguards of the scientific enterprise become particularly important.

The elements of that structure consist of journals, each with its squadron of references, of informal networks by which scientists relentlessly critique each other, of peer review systems by which applications for research grants are appraised, of deliberately harsh competitions within academic departments by which a select few are given tenure and others left to find work elsewhere. This is a rather brutal but unparalleled system for rewarding excellence and culling out that which is shoddy, a system for defeating Gresham's Law as it might otherwise operate in the matter of scientific excellence. It is a tough arena in which to work. Critics are ready to spring on the slightest mistake; daring hypotheses are met with skepticism and bitterly fought. The older establishment is ever the target of brash graduate students and assistant professors. A unique feature of this system is the National Research Council, the working arm of the National Academy of Sciences. Having no interest but the ultimate public interest, it operates as objectively and impartially as possible. The Council is a unique system for definition of the scientific questions relevant to a given problem, the appointment of a committee of the most knowledgeable and competent scientists with assurance of representation of all legitimate points of view and interests, and for the rigorous, impartial, critical review of that committee's report before its release.

The system of science works; but the nonscientist unfamiliar with the rules of the system can misread it, can mistake honest scientific contention for persecution, can interpret angry attacks on controversial assertions as a cover up, can imagine the emergence of "mainstream" views as the telltale of a cabal. As an example, let us consider in some detail the possible biological effects of certain forms of electromagnetic radiation, a matter concerning which controversy has arisen in connection with the acceptability of high-voltage lines for transmission of electricity and with the proposed construction of an antenna which would enable communication with deep-running submarines (Project Seafarer) [See box for brief explanation concerning electromagnetic radiation.]. This was the subject of a recent Saturday Review article entitled "The Invisible Threat: The Stifled Story of Electric Waves," written by SR reporter Susan Schiefelbein (SR: 9/15/79]. That article, largely premised on the writer's selection of what scientific evidence is believable and what is not, is powerfully illustrative of the mischief that can be engendered by a misunderstanding that can be engendered by a misunderstanding of the workings and rules of the scientific enterprise. The article attacks the integrity of a number of individual scientists and of a committee of the National Academy of Sciences. It calls into question the probity of the Academy itself and the validity of the very methods of science. Nevertheless, here we will specifically address the central issue, one that supersedes the problem of prejudiced reporting: the assaying of scientific information in a public arena.

The issue can be stated simply enough: does extremely low-frequency (ELF) electromagnetic radiation such as that associated with high-voltage lines and the Project Seafarer antenna cause biological effects; if so, are such effects harmful in any way?

Obtaining a reliable, definitive answer to that question turns out to be rather difficult. Our environment is suffused by electric and magnetic fields of many origins: the natural stationary and undulating electric and magnetic fields of the planet; local fields from electric wiring, appliances, electric machinery, and transmission lines. Such fields surround all flowing electric currents. To appreciate their magnitude, the natural electric field of the earth, which averages 130 volts per meter, is about the same as that about 12 inches from an electric broiler; the natural magnetic field of the Earth is about 0.5 Gauss, is may be about 5 Gauss in close proximity to an electric can opener, an electric razor, or hair dryer, and much higher under an electric blanket.

Several thousand miles of existing high voltage transmission lines now operate at 765 kilovolts (kV), and carry enough energy to supply the requirements of both Boston and Baltimore. The maximum associated electric field directly under a 765 kV power line is approximately 10,000 volts per meter; the maximum magnetic field is approximately 0.5 Gauss. Both fall sharply with distance from the source. At the edges of a 250 foot right of way, the fields are about 2500 volts/meter and 0.15 Gauss; at 500 feet they are less than the natural levels, 100 volts per meter and 0.01 Gauss. Most houses and other buildings are shielded from the electric field by conductors in their walls and roofs.

In any case, fields do surround transmission lines, people are exposed to them; and they do penetrate through biological tissue. What are the consequences of such exposures? We can readily provide some gross answers. An electric field is created within a person standing under an electrical transmission line but, in general, for reasons having to do with the conductivity of electricity in living tissue as compared with that of air, such an internal electric field, on the average, is thousands or more times smaller than the external field in the air. In considering whether even such an attenuated field is a hazard, we move into difficult and perhaps insufficient experimental science and into controversy.

While there are plentiful data, much of them are contradictory, and some simply experimentally valid. That may seem remarkable, given both the ubiquity of electromagnetic radiation and a long history of curiosity concerning any possible biological effects. Accordingly, let us note some of the contradictory results and then examine several experiments that have been claimed to indicate adverse biological effects but which have not survived appraisal of the validity of their results by the normal procedures of science, yet which, nevertheless, have been awarded credence in the public arena.

Efforts to search for biological effects of ELF have been persistent, catholic, and imaginative. The examination has included searches for possible effects of electric and magnetic fields on the growth and development of plants and animals, for changes in physiological or molecular aspects of cellular metabolism, for genetic and chromosomal changes, for any effects on the behavior of animals or people, in particular on the health of utility linemen working on live 765 kV and 345 kV transmission lines.

The general conclusion extractable from the sum of these efforts is that if a hazard does exist it has not been demonstrated. In the absence of any such proof and in the absence of any theory that predicts such effects, we are left with the unprovable negative: that there does not exist any danger from extremely low frequency radiation at the level at which people are customarily exposed. And we are left also with a burden to improve the experimental methods necessary to this field, and appraise further those small effects that have been seen to ascertain whether they signal real hazards.

Many results have been inconsistent, with superficially similar experiments seemingly finding opposite results. For example, one report claimed a significantly increased human reaction time upon exposure to electrical fields of 3 Hz (Hz=Hertz=cycles per second) as compared to exposure to 10Hz, whereas another report claimed that there was an increased reaction time at 12Hz as compared to 2Hz.

Two studies assessed the effect of 60Hz fields on the growth rate of chickens; one found no effect and the second a decreased growth rate. Such inconsistencies have been obtained repeatedly in the history of science, particularly when, as in this case, the effects sought are small and particularly when they depend on the subjective judgment of the investigator or subject, e.g., estimation of the time of initiation of “fatigue” after exposure to a given field. They can be dealt with by the classical procedures of science; their evaluation is not facilitated by ad hominem attacks.

Aside from inconsistencies, there are flaws in some experiments, incomplete information in others, and a drawing of conclusions not supported by what has purportedly been measured. To illustrate, Soviet investigators have reported a number of complaints—listlessness, excitability, headache, drowsiness, and fatigue attributable to exposure to high intensity electric fields. However, a nine-year study of linemen working on energized high-voltage transmission lines, conducted by scientists at Johns Hopkins University, found no physical, mental, or emotional effects attributable to exposure to high electric fields. Similarly, a study in France of people working and living in proximity to transmission lines found no increase either in the frequency of visits to physicians or use of medications. Studies in Canada, Germany, Sweden, and Japan have failed to show significant effects on electrical workers from the electrical and magnetic fields in which they intimately work.

What is one to do under these conditions? The wary layman should certainly recognize that conclusions from the seemingly positive experiments are tentative at best and perhaps invalid; scientists would attempt to appraise each of the experiments. They would note, for example, that the Russians found similar results in different working environments and then ask whether these variances were properly controlled for, indeed whether there were commonalities other than electric fields that might have been responsible for the reported effects, and how the effects were measured and evaluated. Scientists are made mistrustful by the fact that the array and number of illnesses of Russian workers exposed to high intensity electromagnetic fields were not compared by the same investigators with those of workers not so exposed. Finally, scientists in the United States are now attempting to repeat some of the Russian experiments.

Similar puzzles crop up in experiments with rats and mice. One experiment, for example, reports no effects on either the growth or development of mice exposed for over 10 months to 60 Hz fields of 160 kV/m. In contrast to this benign result is one report that asserts statistically significant decreased water consumption, food intake, and weight gain as well as increased adrenal and pituitary weights and decreased blood steroid levels in rats exposed to a 60Hz 15kV/m field for about a month. This dramatic report is a centerpiece of the Saturday Review article; hence, we shall return to its appraisal below.

A number of experiments have looked for changes in the chemical composition of the blood, principally the concentrations of serum triglycerides (fat), prompted by the posited relation of blood triglyceride levels to various types of heart disease. Human volunteers confined to a small room and exposed to unusually high intensity electromagnetic fields did, one experimenter reported, show higher triglyceride levels than did controls. But, again, one is left on slippery ground for public decision, for another experiment in which humans were exposed, again day and night, to similar electric and magnetic fields found no differences between control and experimental subjects. In a related series of experiments conducted on personnel involved in the Navy's Project Sanguine/Seafarer facility at Clam Lake, Wisconsin, supposedly elevated serum triglyceride levels were found both in these personnel and in matched controls living in Illinois. What is one to make of that, other than methodological inadequacy or operation of chance in these several studies?

One could continue in this fashion, but the leitmotif remains the same: a preponderance of the data showing no effects and some data purporting to indicate small effects of uncertain relation to the public health, all without a guiding theoretical background.

Oddly, the Saturday Review article even derides attempts to understand at a fundamental level the effects of electric and magnetic fields. After indicating that "using a metal ball as a model of the human body, together with his own assumptions of how much heat the body can throw off by means of perspiration and other biological processes, [Dr. Herman] Schwan figured that a person can safely handle an exposure of 10 milliwatts of microwaves per square centimeter of body surface," the author opines that "metal balls and calculations cannot determine what is or is not a dangerous assault on internal organs."

What chutzpah! After passing many errors for many matters, we cannot quite ignore such errors as: stating that Dr. Schwan's funding is largely from the Department of Defense when the bulk thereof derives from the National Institutes of Health; indicating that his research is in "electromagnetics" when it is in biophysics and biology; stating that Dr. Schwan used "metal balls" when he employed spheres of tissue to approximate exposures to electric fields; failing to note that the work referred to, done over a period of thirty years, has been rigorously reviewed and reaffirmed in the scientific literature; and failing to note that Dr. Schwan, a member of the National Academy of Sciences, is perhaps the leading authority in the United States, if not the world, on the interactions of electromagnetic fields with living tissue.

More important than these indefensible errors is the fact that after exhibiting her failure to understand science, the author naively derides the use of one of science's most helpful tools—the use of simple models of complex structures. Models are intrinsic to the scientific method and vital guides to the design of experiments. Hydraulic pressure models, for example, have been applied to studies of blood circulation, with consequent gains in the treatment of circulatory disease; other model systems, including computer models, have aided in the design and syntheses of drugs now used to treat various human ills. The examples are legion. Dr. Schwan's use of models to study the effects of electromagnetic radiation on living tissue was in the classical tradition of science: to study the possible effects of a possibly toxic agent at lower and simpler levels of biological organization as a prelude to organ and whole animal studies.

Let us return to the experiments referred to earlier, those of Andrew Marino of the Veterans Administration Medical Center at Syracuse and his colleagues, who assert that there are quite clear effects which are, in fact, the pillar for the Saturday Review article. The point is not simply to indict that article, but rather to illuminate the consequence when selected experimental results are taken as facts—in this case, by a journalist—deliberately in disregard of the fact that they have been rejected as valueless by the rules by which science guards against shoddy work.

To recapitulate, Dr. Marino published papers claiming that fairly low intensity electric fields cause "stress" in experimental animals, the consequences including stunted growth, food avoidance, and changes in physiological state. To quote from the Saturday Review article: "In one study, rats exposed to an ELF field failed to gain weight normally. In another, three successive generations of mice exposed to ELF fields were stunted. Marino concluded that the animals were exhibiting the classic signs of stress." A photograph used in the Saturday Review article to illustrate these effects shows a test mouse about one third the size of a control mouse.

These results seem provocative. Are they believable? If, indeed, they occurred, were the experimental arrangements such as to preclude other causes of the reported effects? A prime role of committees of the National Research Council is to appraise the scientific validity of experimental results relating to the topic at hand; only scientifically valid, meaningful findings should reasonably figure in public decision making. Upon request from the Defense Department, the National Research Council appointed a committee to investigate the possible biological or other effects related to the construction by the Navy of a very large grid antenna to communicate with deep-running submarines, Project Seafarer. Appointment of the committee is the sole responsibility of the President of the National Academy of Sciences.

The Committee's reviewers found that the cages used to house the experimental animals could have transmitted small electric shocks each time the rats ate or drank. Was it then these shocks or the fields that led to poor feeding by some rats? Did Marino consider such shocks in his conclusions? One doesn't know, but it seems likely that to be "buzzed" when one eats is not to eat well. A reviewer whose professional career has been devoted to the study of stress pointed out that stress can be validly ascertained only by comparisons under precisely controlled conditions. That was patently not the situation in the Marino experiments; thus, the animals that were exposed to ELF were housed three to a cage, while the control animals were each alone in a smaller cage; vibration isolation pads were added to the experimental cages but not to the control cages.

Line concerns beset interpretation of the alleged results of these experiments. The data were themselves paradoxical: Marino reported reduced levels of corticosteroid hormones whereas classic stress research shows that stress raises such levels. Independent analysis of Marino's own data shows that there was no statistically significant difference in the weight of the treated versus the untreated rats! And that picture of the woefully stunted mouse? Perhaps the growth of some mice was indeed stunted, but it must have been a very small fraction of the total. And the experimental procedures used do not unequivocally tell us why; they most surely do not provide scientifically acceptable evidence that extremely low frequency radiation causes such effects.

Yet on this trivial, dubious ground, the article in the Saturday Review built a case for a conspiracy in which are united the National Academy of Sciences and its National Research Council, the federal government, the legal system, and for that matter any scientist who dares to disagree with Marino's claims. QED!

These are not trivial matters. Both the print- and the electronic-news media have utilized the thin tissue of fancied biological effects of ELF to inflame the imagination of the public. At stake are future options for the siting of major electrical power plants and a means for communicating with deeply submerged submarines, obviating the need for a telltale surface antenna. It boggles the mind that some of the news media have been willing to treat such matters with mischievous irresponsibility.

A final matter. Once one chooses, by ignorance or venality, to accept and use only those findings and observations that might buttress a particular point of view, one is forced in time to paranoia so that the fairness and honesty of others is treated as mere cavilling. One shameful example. The Saturday Review article libeled the chairman of the National Research Council's Committee on Project Seafarer, Professor J. Woodland Hastings, Chairman of the Biology Department at Harvard University, stating explicitly that he "publicly lied," yet failed to indicate the nature of the lie or the identity of the public in question.

Upon direct inquiry to the author, we were informed that she, personally, was the "public" in question. The "lie" consisted of Dr. Hastings' statement to her, in 1979, that Dr. Marino and a VA colleague, Dr. Robert Becker, had conducted no research in this field that contributed significantly to current understanding whereas she had in her possession a letter from Hastings to Becker and Marino that indicated that Hastings knew otherwise. That letter, dated three years earlier, was a canvassing letter, written early in the course of the committee study, in which Hastings as committee chairman states that he had been informed that Marino and Becker had conducted investigations relevant to the effect of ELF, and, if that was true, requested that they more fully inform the committee of their work so that the committee could give it due consideration in the course of its deliberations. (Marino and Becker never responded nor did they accept the committee's invitation to attend a committee meeting and present their experiments and findings in person.) By the time of Ms. Schiefelbein's conversation with Dr. Hastings, the committee had long since reported their dismissal of the Marino-Becker findings as essentially without scientific value—as Hastings told her. There was indeed lying reported in the pages of SR—but it was not done by Dr. Hastings.

We end with two quotations. One, taken from the National Research Council report on Project Seafarer, neatly reveals the committee's frustrations with the need to form judgments on sometimes flimsy data: "The Committee has examined a number of cases in which a claimed effect of an ELF field was very likely an effect of something else in the experiment and cases in which no effect was found, but the design of the experiment was such that probably none could have been found even if it did exist. The Committee has not enlarged on these inadequacies on an experiment-by-experiment basis, because, in the absence of an effect (whether real or artifactual), an appraisal of the possible impact of experimental shortcomings becomes an exercise in prophecy, rather than analysis." The *Saturday Review* article contains one statement that we embrace entirely: "The controversy is a complex and many-facted one; it is not well-served by simplified conspiracy theories and personal vendettas." Would that the author thereof had taken her own lesson to heart.