egory fall a lunar interpretation of the nursery rhyme "Jack and Jill" and an explication of the ribald practice of "mooning." All in all, Cain has fashioned an overly earnest yet genial compendium of moonlore.

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Journal of Scientific Exploration, Vol. 7, No. 4, pp. 455–458, 1993 0892-3310/93

Cross Currents by Robert O. Becker. Los Angeles: Jeremy P. Tarcher, Inc., 1990, 336 pp. $19.95 (available from The Sourcebook Project, P. O. Box 107, Glen Arm MD 21057).

Subtitled "The Perils of Electropollution," this book calls for public action to protect ourselves against man-made electromagnetic fields (EMF). We must, according to its author, "act wisely and quickly," because the military and the electric-power industry will otherwise give "little, if any, consideration ... to the potential impact of [EMF] on the health and safety of the public." Furthermore, there is a "conspiracy" by the military to deny the existence of "nonthermal" effects of EMF on living creatures. By "nonthermal" effects of electromagnetic fields Becker means phenomena that occur because of EMF interference with the body's natural electrical and magnetic systems. Our Defense Department carefully allocates scientific research funds only to those projects that will "not challenge the thermal effects standard."

"Thermal" effects relate to the deposition of electromagnetic energy directly, as heat, into bodily tissues. In the U.S.A., government standards have required that such radiation be restricted to energy fluxes less than 10 milliwatts per square centimeter. (In recognition of the fact that that value may be rather high, the standard may in the future be lowered to 1 milliwatt per square centimeter.) In Russia, the standard is already 0.1 milliwatt per square centimeter. There is no mystery about the thermal effects. I allow myself a minor disagreement with Becker in this respect. I believe he is simply wrong when he asserts that (p. 233) "we really do not know exactly how microwaves produce their heating effect, even in the ubiquitous microwave ovens." But thermal effects are not the main objective of the book, as far as I can tell. Becker's emphasis on thermal effects is a distraction. It weakens his insights into the role of nonthermal phenomena.

As a radio astronomer interested in medical applications of radio astronomy and in body electricity in life systems, I found myself fascinated by the author's discussion of nonthermal effects. He finds nonthermal effects all over

the animal world. To his salamanders, frogs, dogs, and people I would add several examples from among fishes. Sharks use natural, built-in, electrical sensors to find prey buried beneath the sea bottom. Their sensitivity is microvolts per meter in salt water. There are also electric eels which, in addition to shocking their prey, generate and control highly-stable electrical oscillations. They apparently use these oscillations to recognize their colleagues in the muddy waters of Amazonia. I can easily imagine that their perception of their close-to-opaque world is an image constructed primarily out of its low-frequency (300 hertz) electrical-impedance characteristics. Tree stumps, rocks, and prey must be familiar to these animals — but in the impedance modality, not visually. Becker notes the use by bacteria and by birds of magnetic materials to orient themselves in Earth's magnetic field. This is as remarkable a story as is the use of electrical fields by fishes. Becker also cites cases of broken or amputated bones that regenerate or of de-differentiated cells of cancer that normalize under the influence of electrical fields. Without question within each of us lies a potential, either realized or unrealized, for electrical and magnetic sensitivity. DNA and a billion or more years of evolution make some life forms better at it than others. This capability is latent within all of us.

But now, as electrical technology surrounds us, "The exposure of living organisms to abnormal electromagnetic fields results in significant abnormalities in physiology and function." I believe that the issue remains undecided whether EMF is the actual peril that Becker describes. Health *Effects* of *Low*-Frequency Electric and Magnetic Fields (Oak Ridge Associated Universities, 1992; U.S. Government Printing Office, Pub. No. 029-000-00443-9) concludes that EMF "does not appear to constitute a public health problem." Nancy Wertheimer, cited by Becker as the discoverer of the effects of three-milligauss magnetic fields at 60 Hz on childhood cancer (p. 204), recently stated that "we don't know if there is any risk. I do think you have some kind of physiological effect going on" (quoted from The Boulder Daily Camera, 3 December 1992). In the same news article, Frank Barnes, a respected electrical-engineering professor at the University of Colorado in Boulder, is quoted as saying that "it is an open question whether these fields are dangerous and cause disease ... since we don't have a closed chain that shows how you get from mechanisms ... to health effects." While the respected publication Consumer Reports (November, 1989, page 716; October, 1991, page 697) stated that it would be prudent, for example, for pregnant women to avoid the use of electric blankets, it did not say that the EMF "peril" has been demonstrated conclusively.

Becker's is not an unequivocal demonstration. He is at best shaky about the laws of physics. It may be that I myself have overreacted to his errors. Because the same errors appear in many popular articles on the subject of the perils of EMF, even in Consumer Reports, I must cite at least one so that readers can be forewarned. In CR, November, 1989, page 715, I read " ... that 60-Hz fields received scant attention until recently ... [because these] low-frequency fields transmit very little energy compared with other forms of electromagnetic ener-

gy. Unlike X-rays ... such fields can't break chemical bonds ... " This argument also appears repeatedly in Becker's book and is, I believe, fallacious. It is a mistake to say that low-frequency radiation fields "transmit little energy." Electromagnetic radiation carries energy in the form of photons. Each photon has energy strictly proportional to its frequency. The constant of proportionality is known as Planck's constant. This photon energy must be of the proper value for there to be radiative processes of ionization or excitation in individual atoms. X-radiation creates radiative ionization because its photon energy is high. Photons also describe electromagnetic radiation at extremely low frequencies, even 50 to 60 Hz, those associated with electric-power-distribution systems. At 60 Hz the photon energy is very low. But the field intensity can be very large, corresponding to an enormous flux of photons.

Both *Consumer **Reports*** and Becker appear to me to confuse electromagnetic radiation and electric or magnetic fields. Radiation fields are the playground, so to speak, of photons, and always involve both electric and magnetic fields. Fields of either variety can exist without the presence of radiation. Those fields do not represent propagating energy, that is, radiation. In well-designed power distribution systems the non-radiating fields should be very small and the radiating fields non-existent. Of course, these are ideals never actually achieved. The effects might nevertheless be as harmful as those of radiation and that is exactly why Becker's discussion could be useful. But, his failure to distinguish propagating from non-propagating fields makes his logic sometimes difficult to follow.

Becker was motivated to undertake studies of the effects of EMF on living organisms because, thirty years ago, he perceived a connection between human behavior and such cosmic phenomena as geomagnetic storms. It is clear that his conclusions about EMF pollution originate in his belief that evolution, and perhaps even the creation of life, was driven in Precambrian times by micro-pulsations in Earth's magnetic field. He believes that micro-pulsations "would have been particularly strong" then. He also believes that the past 25,000 years have been singularly free from great geological disturbances and, therefore, from effects of abnormal, natural, EMF. I cannot agree that the most recent 25,000 years have been free of great geological disturbances. Eleven or twelve thousand years ago the last ice age came to a close, caused by or followed by major modifications to the climate of all the continents, huge rebounds of land masses previously depressed under the burden of kilometers-thick ice sheets, and drowning of shore under seas that rose more than 100 meters. This is not irrelevant, because solar activity, the ultimate source of the energy that drives geomagnetic storms and micro-pulsations, may, in its ebb and flow, be responsible for some parts of the ice-age phenomenon. I know of no evidence that geomagnetic disturbances in Precambrian times would have been particularly strong (or, for that matter, would not have been).

In his call for action, Becker states that "the only persons who can make the final decision as to risk versus benefits [of electrical technology] are those who would be at risk." I would agree with him if risk and benefit decisions in-

volved only the people who are at risk. For example, a motorcyclist might riskily ride without a helmet but he may become involved with a car driver who, perhaps even recklessly, makes him crash. The driver or the general public may end up paying for the life-long rehabilitation of the cyclist only because he imprudently failed to wear a helmet. I argue that the general public therefore has an interest in whether the cyclist wears a helmet or not, or even whether he rides a motorcycle at all.

In the EMF case, the comparison of risk versus benefits is harder to work out. This risk has been very difficult to demonstrate. On the other hand the benefits of electrical technology are extraordinary. To propose changing this equation without compelling logic appears reckless to me. Becker writes well and non-scientists will find many of his arguments compelling. But they are superficial and ultimately unconvincing. To me his strong words seem out of place and somewhat irresponsible.

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