Letters

Hormesis

Recently, the possibility of beneficial effects of low-level ionizing radiation was the topic of Policy Forum discussions by Leonard A. Sagan and by Sheldon Wolff (11 Aug., pp. 574 and 575). The concept of hormesis, or stimulation, smacks of homeopathy: a tiny amount of something deleterious, in this case ionizing radiation, is considered helpful. An important consideration is missing from both discussions.

The lowest dose of ionizing radiation mentioned in either discussion that triggers repair mechanisms, 0.5 cGy, produces a total concentration of 3 nM oxyradicals. The *steady-state* concentration of radicals from metabolic processes involving oxygen is of comparable magnitude, 0.1 to 1 nM (*1*). Therefore, it would be most surprising if such a small *transient* concentration were to cause damage sufficient to activate repair mechanisms. Any discussion of the beneficial, neutral, or harmful effects of low-level ionizing radiation is seriously flawed if the "background" flux of oxyradicals is not taken into account. That oxygen toxicity and radiation damage have a mechanism in common was first suggested in *Science* 35 years ago (*2*).

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REFERENCES AND NOTES

1. This concentration range was calculated [W. H. Koppenol and J. Butler, *Adv. Free Radical Biol. Med.* **1**, 91 (1985)] with the help of the steady-state approximation, a superoxide generation of 19 nmol·min^{-1}·g^{-1}, as found in lung tissue [I. Fridovich and B. Freeman, *Ann. Rev. Physiol.* **48**, 693 (1986)], an estimated superoxide dismutase concentration of 1 μM, and a rate constant of 2×10^9 M^{-1} s^{-1} [M. E. Fielden *et al.*, *Biochem. J.* **139**, 49 (1974)] for the scavenging of superoxide by superoxide dismutase. In the absence of superoxide dismutase, superoxide decays by spontaneous dismutation, which is a less efficient process and results in a steady-state concentration of 1 μM.
2. R. Gerschman, D. L. Gilbert, S. W. Nye, P. Dwyer, W. O. Fenn, *Science* **119**, 623 (1954).

Several fundamental flaws appear in the argument of Leonard A. Sagan (Policy Forum, 11 Aug., p. 574). First, the term "hormesis" is applied collectively to a diverse conglomeration of species, biological material (organism, tissue, or cells), and types of response (stimulation or beneficial response). Second, Sagan does not define the desired end point for hormetic effects in humans, presumably a *net* beneficial effect to the whole person from low-level radiation exposure, or the value judgments needed to determine that end point. Third, he ignores the perturbing effect of variance in exposures from the natural radiation environment on the ability to measure hormetic contributions to health effects. Fourth, from an observational standpoint, in many instances an apparent hormetic effect may be in reality indistinguishable from a threshold effect.

Without clear tenets for the definition and determination of beneficial hormetic effects in humans, the thesis for such effects remains as unproven as assuming risk at any dose level. No one doubts the presence of repair mechanisms in the body, and studies on immune systems may, in time, show the existence of threshold or hormetic phenomena of net benefit to humans. Nevertheless, to predicate public health policy on present knowledge of hormesis is premature. To paraphrase the Queen of Hearts from *Alice's Adventures in Wonderland*, Sagan seems to suggest "Policy first—proof afterwards."

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Solar Power

Daniel E. Koshland, Jr.'s editorial "Solar power and priorities" (25 Aug., p. 805) was a powerful statement—until the place where he listed who should pay "combined and dedicated attention" to the problems of global warming. Notably unnamed were the Earth system scientists—geologists, whose unique record of time provides the data for identifying and evaluating past periods of global warming and their consequences; ecologists, whose integrated view of organism interactions with other Earth systems can document and evaluate the patterns of historical change; climatologists, whose synoptic views of atmospheric changes on both geologic and historic time scales help to sort out real change from the noisy weather signal; and oceanographers, whose domain is both the buffer and the instigator of many aspects of climatic change. It is these scientists whose special expertise is required in highly complex and interactive problems such as global warming—and in other major areas of societal concern such as hazard mitigation, solid and toxic waste disposal, land utilization, air and water pollution, and overpopulation. This is not the group that immediately comes to mind when I read "physicists, chemists, biologists. . ." in the editorial. Science may need the highly visible (particle) physicists, (molecular) biologists, or (structural) chemists, but global change needs the attention of those scientists who work with Earth systems; and the engineers, city planners, economists, efficiency experts, and politicians need to know the difference.

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I applaud *Science* for continuing to support the development of energy conservation and renewable energy sources as means to sustain our environment and maintain economic growth. I note, however, that it has been the policy of the U.S. government to drastically cut support for these technologies just as the issues of global warming and international competitiveness have come to the nation's attention.

The story of photovoltaics (PV) provides one example of how the United States has failed to exploit these technologies. PV is an attractive means of generating electricity while reducing the release of carbon dioxide and sulfur dioxide. In the past decade its price has fallen more than tenfold and its efficiency has increased threefold. PV is now the least costly method of electricity generation in most off-grid applications. Major improvements in laboratory cells have been reported (*1*) recently. Scaleup of pilot plants should drop the price by a factor of 2 to 3, where it will be cost competitive for bulk peak power generation. However, the PV industry needs a clear signal that a market will be available before it can justify the capital investment needed to convert R&D into a marketable product.

Until 5 years ago, the United States was the clear leader in PV technology. During the past 8 years the DOE budget for the PV program has dropped from about $150 million to $35 million. The Japanese, German, and Italian governments now spend more on PV R&D than does the United States. While the European Community (EC) spends $5 million per year promoting PV exports, the United States spends $1 million annually on export promotion for all renewable energy technologies. When fuel costs are considered, PV is the least costly method of providing power for vaccine refrigeration and water pumping in Third World countries, but U.S. aid agencies continue to specify fossil fuel–powered refrigerators and water pumps. Meanwhile, the EC is directing $30 million for PV-wind water pumping to its African development programs.

U.S. PV manufacturers held more than 80% of the world market in 1980 but, as other nations developed their PV industries, the U.S. market share dropped to less than 50%. Due to poor research and market conditions in the United States, the leading PV manufacturing company, ARCO Solar, was recently sold by its parent oil company to a German investor. Just at a time when PV technology has advanced to a level where we can see that it is becoming cost competitive with conventional energy sources, the United States seems to be conceding the game to our international competitors.

Similar tales can be told of other renewable energy and conservation technologies. The United States has the opportunity to be a leader in the fight against global warming and atmospheric pollution and to gain economically from those efforts. To succeed, the federal government must reverse its policy of phasing out R&D and market support for energy conservation and renewable energy technologies.

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1. R. Pool, *Science* **241**, 900 (1988); H. M. Hubbard, *ibid.* **244**, 297 (1989); R. McCormack, *Energy Daily*, 11 August 1989, p. 2.

SSC Test Magnets

Mark Crawford's News & Comment article (25 Aug., p. 809) creates several misconceptions about the development of dipole magnets for the Superconducting Super Collider (SSC). Most serious is the implication that a report by an expert panel reviewing the magnet R&D program was somehow withheld from responsible officials. The fact is that at all stages, this review and its outcome have been discussed openly with Congress, the Department of Energy (DOE), and the scientific community.

In February 1989, I testified before both House and Senate subcommittees on energy research and development and reported on problems that had been seen in some SSC test magnets. At that time, I indicated my intention to appoint an SSC Collider Dipole Review Panel to study the magnet R&D program and to make recommendations to me. The panel was established, and I asked it to provide a rigorous, critical review of the program. The panel met in April 1989 and provided a draft report in May. That month, I presented the main conclusions at a meeting of DOE's High Energy Physics Advisory Panel in public session. When the report was completed in June, a preface was added and the report was issued as SSC Laboratory Report SSC-SR-1040. The report is available to anyone who requests a copy; it has never been "closely held."

Crawford's article also projects an excessively negative tone about the technical status of the magnet R&D program and the accomplishments of the national R&D effort that was led by the SSC Central Design Group. The tone is misleading. In fact, test magnets produced in the program verify the basic design concept. Nevertheless, when the panel was assembled, a number of issues remained for the magnet R&D program, among them the questions of operating margin, reliability, manufacturability, and reproducibility. These are the points that are emphasized in the review panel's report. They have long been recognized as critical and are basic to the next stage of the development program, which will involve major industrial participation in addition to national laboratory work.