the signature is so unique that the transition can be detected directly. Another is in the measurement[1] of the small electromagnetic interaction of the neutral kaon with the electron. In that experiment, A was the much larger strong interaction of the kaon with the nucleus, which could be made to interfere with B, the K–e interaction. The experiment consisted of measuring $|A+B|^2$ and $|A|^2$ separately and thereby isolating an effect. This technique involves taking the difference of large numbers, where one has to pay very close attention to systematic uncertainty. It is possible that using the same amount of beam to detect the K–e interaction directly (with an energetic electron emerging from the target) would have produced a more significant result.

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Henry Torrey's Signal Nmr Achievement

Frederick Seitz's excellent article on World War II research on silicon and germanium semiconductors and transistor devices (January, page 22) describes Henry C. Torrey's leadership of the crystal diode work at the MIT Radiation Laboratory. It was not mentioned and is in general not well known in the physics community that Torrey also found time in 1945 to pioneer in another research direction that opened the door to a major new field of 20th-century physics, namely nuclear magnetic resonance.

In earlier work at Columbia University under I. I. Rabi, Torrey gained the background that later, at MIT, gave him unique insight into the physics of spin systems and led to improved estimates of spin–lattice relaxation time and of the rf voltage level needed to avoid saturation. This expertise made possible the design of the first successful experiment on nmr in solids, in 1945,[1] after previous workers had failed.[2] Torrey's collaborators in the experimental implementation of nmr were his MIT coworkers Edward M. Purcell and Robert V. Pound, who became well known for their later nmr research with Nicolaas Bloembergen on solids and liquids, carried out at Harvard University. The experimental skill of the MIT group, perhaps sharpened by their Rad Lab experience, is attested to by their inspired combination of an off-the-shelf oscillator, electromagnet and voltage amplifier, which produced an observable proton nmr signal with a paraffin sample on the first attempt, within the experimental parameters estimated by Torrey.

It is somewhat surprising that in 1995, the 50th anniversary of the discovery of nmr, this historic first has not received wider recognition and some form of commemoration. The detailed story of this episode, including the roots at Columbia University, the flowering at MIT and the various contributions of the participants, remains an inadequately reported chapter in the history of physics.

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Open NSF's Purse to Those Outside Academe

I wholeheartedly agree with Henry Ehrenreich in "Strategic Curiosity: Semiconductor Physics in the 1950s" (January, page 28) that it is important to protect the position of "generic," "curiosity-driven" or "basic" research within the National Science Foundation. Surely there are other agencies, such as the National Institute of Standards and Technology, that are better suited to playing the lead role in "strategic" research. That is not to say, however, that changes at NSF should not be made in light of changing conditions within the physics profession. Specifically, I have in mind the traditional rule that the NSF-sponsored single-investigator proposal, a key component of basic research, is usually limited to researchers within the university community.

In the current situation, graduating physicists who go on to careers in government, industry, nonprofit institutions, contract research and development centers and self-employment are excluded from principal-investigator status in a broad range of NSF programs directed toward basic research. This would be a majority of graduating and recently graduated PhDs. I suggest that as it is improper to deny participation based on gender or race, so too is it inappropriate to deny participation based on institutional affiliation. This nation needs to take advantage of the possible contributions of *all* physicists in this increasingly competitive world, especially in an era of ever tightening Federal budgets, when it is imperative to make the fullest use of available expertise.

There seems to be general agreement that we are producing more PhDs than there are traditional academic jobs at universities. This is not necessarily a bad thing, and some people have noted that physics training provides a rigorous background suited to a whole host of careers. If leaders within the physics community itself would set the good example of attempting to open up NSF research funding to all qualified physicists, regardless of institutional affiliation, this would provide a powerful example of the usefulness of physics training beyond traditional university research. Also, by looking more at the researcher than at his or her place of employment, I believe we would be taking a necessary step in increasing the stature of the physicist as an independent professional. Such a stature would serve well in enabling physicists to thrive outside traditional roles.

As it may be artificial to distinguish between strategic and curiosity-driven research, so too might it be artificial if not out of date to distinguish between university-based and otherwise-based researchers. And it might be wrong, too, if the purpose of Federal support for basic research is the advancement of the best possible physics.

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Can Coal Combustion Breed Pu in the Sky?

The conventional wisdom regarding plutonium in the environment is that its halflife of 24 400 years is sufficiently short that no natural-source plutonium remains in the biosphere, and any plutonium in the biosphere must have originated from breeding plutonium in uranium for nuclear weapons and reactors. This "wisdom" may be flawed, however, and we must ask if plutonium is being bred in the biosphere by natural, but unidentified, means.

The mechanism for breeding plutonium is well known: A uranium-238 nucleus plus one neutron becomes plutonium-239 after passing through some intermediate steps. Trace element analysis of coal shows significant quantities of uranium and thorium. For example, Environmental Protection Agency analysis[1] of 5000 samples of coal from varied sources gives an average uranium concentration of 1.3 parts per million; thorium is about 3.2 ppm. International Atomic Energy Agency data[2] list average uranium concentration in coal to be 2.08 ppm and that of thorium to be 4.58 ppm. Is the ^{238}U released in coal combustion a feedstock for production of plutonium? If so, a natural source of neutrons is required.

Cosmic-ray studies from the 1950s and '60s showed that the biosphere sustains a small but constant flux of neutrons with broad ranges of intensity and energy. Interactions with available nuclei over these ranges are not well understood. However, since the neutron absorption coefficients of uranium and thorium are about three orders of magnitude greater than those of atmospheric constituents (oxygen, nitrogen and so on), these heavy metal nuclei present much larger targets for neutrons when suspended in the atmosphere. Coal combustion provides a suspension mechanism. Coal combustion also releases thorium, which is another natural source of neutrons. Mostly composed of thorium-232 nuclei, natural thorium has an absorption coefficient of around 7.5 barns, similar to that of uranium. But thorium-233 goes to 1500 b and fissions when another neutron is absorbed. Although rather short-lived, this isotope is a secondary source of two or three neutrons arising from each fission. And fissionable ^{235}U constitutes about 0.711% of natural uranium. Radioactive fission fragments result from fissioned nuclei and may accumulate in the biosphere. The heavy metals in coal combustion and reaction products accumulate in the biosphere. For example, based on the EPA analysis,[1] more than 5.2 tons of uranium, more than 12.8 tons of thorium and about 0.33 tons of radioactive potassium-40 result from each 1000 MW_e of coal-fired utility power production.[3] All this material participates in wind and water movement and the food chain.

The radiotoxicity of plutonium is more than 11 orders of magnitude greater than those of natural uranium and thorium. Thus tiny quantities of plutonium bred through entirely natural mechanisms could significantly alter the radiotoxicity of the biosphere.

The developed countries burn billions of tons of coal annually, and expanding industrialization as the remainder of the world fuels its economic growth could add significantly to the flow of radiological material into the biosphere. According to published data,[4] the background level of radioactivity in the biosphere increases by about 4.27 microcuries for each ton of coal burned. Given the 5100 million tons of coal produced (and assumed burned) worldwide in 1991, the radioactivity burden of the biosphere increased by 21 777 Ci of long-lived radioisotopes in that year alone. Integrating over 100 or more years of continually increasing coal combustion yields millions of curies.

With so many variables in this problem, some of whose amounts are known and some unknown, arriving at a successful model for tracking and anticipating coal-source biospheric radioactivity and radiotoxicity burdens, and their impact on the world for near-eternity, appears to be another grand challenge for science.

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Pulsar Magnetosphere Theory: A Closed Book?

Our book *Physics of the Pulsar Magnetosphere* (Cambridge University Press, 1993) was reviewed by Jonathan Arons in your October 1994 issue (page 71). We are sorry that our book caused Arons such painful disappointment. Here are only a few examples of his absolutely negative reaction: "this survey is rather superficial," "contains observational *faux pas*," "fundamental discrepancy," "fatal flaws," "sweeping claims," "a detailed example of how mathematical erudition can triumph over physical good sense." Meanwhile, the scientific side of the problem and our formulation of its physical background were almost completely left out of this unusual review.

The physical ground of the whole complex of processes in a pulsar magnetosphere is exceedingly simple and natural. Everything comes as the result of fast rotation in a vacuum of a strongly magnetized conducting body, namely a neutron star. The rotation creates an electric field whose action, in the presence of the strong curvilinear magnetic field of the star, leads to the effective generation of an electron–positron plasma, that is, to the formation of a magnetosphere. The corotation of the plasma in the magnetosphere induces corotation currents, owing to which distant magnetic field lines open and go to infinity. Plasma travels away from the star along these lines and therefore must be continuously generated in the vicinity of the magnetic poles. This is just the cause of the lasting activity in the region of the magnetic poles, which leads to a powerful directed flux of pulsar x-ray, gamma and radio emission. Deceleration of the neutron-star rotation, induced by electric currents, provides the energetics of all the processes. The leading role in the creation and maintenance of pulsar activity is played by the longitudinal current that circulates in the magnetosphere. The role of the surrounding medium is of much less importance. That allows one to treat the whole problem on the basis of a self-consistent theory.

Our book presents the state of the art in the theory, as well as the vast body of observational material. We cite more than 500 papers and discuss the material using both a quite simple physical description and the rigorous mathematical language of the modern plasma theory. A special chapter is devoted to detailed comparison between the theory and a set of observations. Naturally, the book gives only fundamentals of the theory. For a number of important problems (some of which are formulated in the book) the complete theory has not yet been developed. We believe that the general physical approach and mathematical methods discussed in the book will eventually be used to treat the unsolved problems. An analogous technique could be applied to the description of the electrodynamics of other magnetospheres, including the magnetosphere of the Earth.

We believe that Arons's unconventional review could bring additional interest to our book and serve as an advertisement. Unlike Arons, we recommend that readers read both the review and the book, so that they will be able to assess the scientific objectivity of the reviewer.

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ARONS REPLIES: I am sorry my review of *Physics of the Pulsar Magnetosphere* caused the authors such dismay. Many of the physical points discussed in the above letter were in fact mentioned in my review, although in a somewhat different and