ing cooling by continued brittle deformation, nor that steep "breakaway" faults connect to the surface.

Of course, the elephant has other parts as well; the Earth, too, has striking contrasts in material properties, as well as complexities imposed by deformation evolving through time. But on the largest scale, deep reflection seismology supplies the connection between subhorizontal normal faulting and Coulomb-theory steep normal faulting.

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The Science Doctorate

I take exception to the sentiment expressed by respondents on the subject of employment opportunities for those with science Ph.D.'s (Letters, 8 Dec., p. 1553). Those writers suggest that the commitment to attainment of the doctoral degree ought to be motivated by "sheer love of research" rather than considerations of career. Such advice may have been appropriate for a relatively small number of 19th-century gentlemen of leisure, but it is disturbingly out of touch at the end of the 20th century. Among recent doctoral students in science whom I have known, not one could have afforded the investment of time and the attendant retardation or permanent attenuation of income and net worth demanded by their programs were these not potentially offset by improved employment opportunities believed to be available to holders of the doctorate.

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In reading the letters concerning Ph.D. employment, I was struck by a recurring theme—that the attainment of scientific education be the goal in and of itself—and that for the best and brightest students future employment should be a secondary consideration. There is a flaw in this argument, however. While one can obtain an art degree and continue to paint in the attic, or attend a conservatory and then play in a community orchestra, it is not possible to earn a Ph.D. and then set up a molecular biology laboratory in the garage while flipping hamburgers to earn a living. A scientist in this day and age can only enjoy his or her chosen field by being employed in it. Because of this, and because of the time taken out of one's most productive years to attend graduate school, the scientific community has an obligation not to overproduce Ph.D.'s.

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Stagnating budgets for the National Institutes of Health and the National Science Foundation have caused these agencies to turn down large numbers of otherwise fundable grant proposals, which has led to a reluctance of universities to hire postdocs to tenure-track positions. This, in turn, has led to a surge in the number of underemployed Ph.D.'s. The root of the problem, therefore, appears to be the unwise reduction of science budgets by the U.S. government. The increasing number of noncitizen postdocs, the appearance of perennial postdocs, and the sudden focus on alternative employ-

ment for Ph.D.'s are consequences of the restricted funds for scientific research.

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I applaud the attention given by T. P. Smith III and J. C. Tsang (Policy Forum, 6 Oct., p. 48) to the need for more teaching opportunities as an integral part of graduate education. I suggest one example of how this can be done. In the late 1970s, a group of our microbiology Ph.D. students from the University of Virginia Medical School was invited to teach an upper-level undergraduate course in immunology at Randolph Macon Women's College (RMWC), a nearby liberal arts college. They were paid a small stipend by RMWC, but their primary motivation was to gain teaching experience. They gave the course under the supervision of an RMWC faculty member, who met regularly with them to critique their performance.

It was a winning situation all around. The biology students at RMWC got an excellent course in immunology, while the graduate students gained a much more intensive teaching experience than is provided by the kind of monotonous duties—usually as a lab instructor in an introductory course—that are normally assigned to graduate teaching assistants. Most important, through the act of teaching science at a high level, these students learned an important truth—that teaching can be an important part of the learning process for teachers as well as for students.

Universities must increasingly provide this kind of meaningful teaching experience within the Ph.D. framework, instead of simply using graduate students as cannon fodder. Teaching experience will become even more important as a larger proportion of Ph.D. students prepare for careers in industry. One of the most valuable skills in an industrial setting is not simply the ability to generate and develop ideas, but the ability to communicate these ideas to co-workers, management, and the general public.

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With respect to the shape of the Ph.D. program of the future, we would like to describe the industry-oriented interdisciplinary Ph.D. program that we have evolved during the past 5 years during our maturation as a National Science Foundation–funded engineering research center in a medium-sized state university.

Students must be well trained in established disciplines in order to be valuable members of interdisciplinary research teams, so each student studies in his or her own department in addition to participating in the Center for Biofilm Engineering (CBE). The CBE is a supradepartmental entity with good funding and contiguous space that provides each graduate student with specialized courses, two seminar programs, and membership in one or more interdisciplinary research teams led by principal investigators from engineering (chemical and civil) and from letters and science (microbiology). During our first 5 years of operation, we have already produced 13 Ph.D.'s with sound training in classical disciplines and with experience working in the truly interdisciplinary teams that are required for research in this borderline area between science and engineering.

The supradepartmental structure of the CBE also provides an optimal interface with industry. Each year, four to six graduate students spend between 2 and 6 months working in the research operations of member companies, and more than half of the Ph.D. graduates of the center eventually accept jobs with the companies with whom they "interned."

Even without the generous support of a special federal program, the creation of supradepartmental entities that combine research strengths in one or more traditional departments are well within the capabilities of many research-intensive universities.

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Wallace M. Manheimer advocates the elimination of postdoctoral positions (Letters, 8 Dec., p. 1553). He mourns the conditions which he contends makes it impossible for a postdoc to do his or her best work, the absurdity of requiring Ph.D.'s to obtain additional education before beginning permanent positions, and the negative impact of postdoctoral appointments on a person's family life. In short, Manheimer argues that postdoctoral fellows are an exploited segment of the scientific community.

I have been a postdoctoral fellow, mentored several postdocs, and have been involved in the administration of postdoctoral fellowship programs. A postdoctoral fellowship can be a period of great professional growth, and possibly the most productive period of a scientist's research career. The opportunities to refine newly learned skills and further intellectual growth, unfettered by the responsibilities

that come with a permanent position, are unparalleled. Also, being exposed to a new network of scientific colleagues contributes to building a strong foundation for a career in science. A postdoctoral fellowship can often be the prelude to a permanent position, particularly if the fellowship is at a government or industrial laboratory. Postdoctoral fellowships can enable new Ph.D.'s seeking a faculty position to get a head start on grant preparation. Stipends often approach or are comparable to those of entry-level positions at the host facility. Few, if any, economic hardships are imposed by accepting most postdoctoral fellowships. As far as being destructive of family life, that is a matter of perspective. A professional position tenured at the same location or with the same company for a working lifetime is exceedingly rare, even for employees.

If Manheimer's arguments against postdoctoral positions are accepted, what are the realistic alternatives? Employers are, at least, conservative when hiring and, in many cases, not prepared to make long-term commitments to staffing research programs in the current economic environment.

Manheimer does not take into account the negative impact of eliminating postdoctoral positions on the scientific infrastructure of the United States. The influx of new scientific ideas and the cross-fertilization among research groups at university, government, and industrial labs promoted by hosting postdoctoral fellows is essential to scientific progress and cultivates productive relationships within the scientific community.

While I would agree that it is possible to exploit postdoctoral fellows, I believe that wholesale elimination of the position would not benefit anyone, least of all new Ph.D. scientists. Other checks and balances should be in place to provide postdoctoral associates with meaningful research experiences and access to the many opportunities provided by these appointments.

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Gene Therapy: False Expectations?

As a former member of the Recombinant DNA Advisory Committee (RAC) of the National Institutes of Health (NIH) (1992–1995), I was interested to read the News & Comment article (15 Dec., p. 1751), appropriately titled, "Less hype, more biology needed for gene therapy." Shortly before my departure from the RAC, I sent a letter to the NIH and the Chairman of the RAC stating exactly the same message. Unnecessary hype after each RAC session trumpeted the number of protocols approved. However, the end product—the results and consequences of gene therapy experiments—received scant notice, if any. I expressed my fear that the public was being misled. Too many false expectations are being raised in the minds of the public.

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Letters to the Editor

Letters may be submitted by e-mail (at science_letters@aaas.org), fax (202-289-7562), or regular mail (*Science*, 1333 H Street, NW, Washington, DC 20005, USA). Letters are not routinely acknowledged. Full addresses, signatures, and daytime phone numbers should be included. Letters should be brief (300 words or less) and may be edited for reasons of clarity or space. Letter writers are not consulted before publication.