Science Funding

I was one of the respondents in Leon Lederman's recent survey of science funding and now respond to his report "Science: The end of the frontier?" (Supplement, 11 Jan.). He has well captured the mood of the research community and the financial situation in which we operate. It is hard to do research if one spends most of one's time writing proposals, and even harder on $0 support. But I disagree with his conclusion. Demanding 8 to 10% annual real growth classifies one (at least in Congress's mind) as just another greedy interest group.

The assumptions Lederman makes in asking for rapid growth are not justified: The number of academic scientists should not grow faster than the population, because the fraction of talented people is not increasing. The complexity factor growth is also spurious; it disguises a shift to technician- or contractor-dominated big science. A scientific field or technique whose real costs grow rapidly is mature and should give way to new problems or methods where progress is led by new ideas, rather than by more dollars. A good example is the replacement of massive high-pressure presses by tabletop diamond anvil cells.

The real question is why, during several years of real growth in science funding, the situation of the university scientist should have gone from tight but manageable to catastrophic. The unpleasant answer is that big science, middle science, centers, and academic mini-empires have swallowed all the growth and much of the old money, leaving sharply reduced support for the typical university scientist with a good record and good ideas, but no clout. It is up to the leadership of the scientific community to reverse this. Only then will we foot-soldiers follow in demanding more support for science in general, for only then will there be a chance that the new money will go to original research, rather than to overruns on some gigaproject or to a hundred new Centers for the Study of Grantsmanship.

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Lederman is essentially correct that funding per scientist is much less today than in 1968 and also that equipment and experiment costs have gone up considerably. The success rate for grant applications shows how severe the strain on the individual investigator is. Unfortunately, there is a fundamental problem with achieving adequate funding per investigator: such a level of funding leads to an ever increasing number of Ph.D.'s. A professor with an adequate level of funding may have a technician, several Masters students, and a Ph.D. candidate or two. These students soon graduate and require employment, and the professor starts training a new batch. Successful grant-getters may train 10 to 20 Ph.D. students during their careers. Even if many faculty, such as those at small colleges or those who go into administration, never train any graduate students, there is still a strong tendency for the system to grow. Whereas this may not be a problem in engineering, where Ph.D.'s are likely to be hired by industry, in many fields the main employer is the educational sector, which has been experiencing sluggish growth at best recently. If universities expect every faculty member to be a great grant-getter to get tenure (and the job ads seem to indicate this), and if adequate funding were available, then there would result a huge glut of Ph.D.'s unable to find a job: exactly the situation that has obtained for the last 10 years. The factor that seems to be cooling off the oversupply of Ph.D.'s in the last few years is in fact the shortage of funding which has led to reduced numbers of new Ph.D.'s being trained. The only way in which most faculty members can be adequately funded without creating an oversupply of new Ph.D.'s is to have a large number of jobs for Ph.D.'s outside the educational sector, such as those at the U.S. Department of Agriculture, the National Institutes of Health, and other agencies, relative to the pool of "reproducing" faculty who train new students. Merely getting more funding from Congress may make current faculty happy, but it will be at the expense of those who go for an advanced degree and then are unemployable.

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As a British scientist, I found "Science: The end of the frontier?" perhaps more disturbing than will have most American scientists. It was the comparison of the impoverished, dejected state of U.S. science departments with that of the supposedly flourishing university laboratories of western Europe that was so striking.

As can be seen from my address, I am now working in the States. So are several hundreds, if not thousands, of other Brits. Why? Because when we get here and see the huge offices, each with only one professor working in them, the vast labs stuffed with the latest equipment, the number of scurrying technicians servicing that equipment, and the administrative support that professors receive in their teaching and research, we cannot believe that we suffered so long the condition of British universities before packing our bags and adding to the influx that we started 300 years ago.

I could suggest that "Thou protest too much." I could suggest that one go to an African university, where they can't even get paper to write on, let alone equipment to work with, before one complains so bitterly. Instead I'll suggest that U.S. politicians look at the poor man of western Europe, namely Britain. Compare the morale of its universities, the status of its teachers, and the level of its scientific and economic performance, with those of Japan, France, Germany, and the other Summit 7 countries. Then one can see where the United States might be in 20 years if it continues to allow short-sighted market forces to erode the science and the scientists who are surely the basis, not just of a successful economy, but of a society that can cope with the immense ecological, engineering, medical, and social challenges that a burgeoning human population and a warming climate are going to throw at it.

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The extracts from scientists' letters included in Leon M. Lederman's "Science: The end of the frontier?" are very persuasive about the sorry state in which American scientific research finds itself with respect to funding. As Lederman indicates, this situation can be a tragedy for the nation.

Lederman surveyed leading scientists in "the 30 largest research-oriented universities" and "20 . . . less research-oriented institutions." He has been working actively with the Chicago school system. These approaches are all to the good in Lederman's efforts to enhance scientific literacy in the general public. But in contacting school children on the one hand and the scientific elite on the other, Lederman seems to be ignoring an important component of the mix, perhaps its most important component—the general public itself, including Joe Six-pack.

The national budget, including funding of scientific research, is a political issue. It is a truism that "American politics is local politics." Congress is very responsive to opinions and pressures from the grassroots—their home districts. No political initiatives, Lederman's or anybody else's, are likely to succeed if they lack grassroot support.

I write on behalf of the Iowa Committee of Correspondence. This organization was part of a grassroots network in 50 states, which in the early 1980s worked to defend the teaching of evolution from creationist attacks. We helped to win victories for evolution in the courts and state legislatures, and we kept creationism out of the schools.

Today our organization survives and thrives, but instead of battling creationism we focus on what we see as a more fundamental issue—public understanding of science. To this end we have been conducting in the upper Midwest, along with other activities, a series of public meetings on understanding science.

I applaud Lederman and AAAS for their efforts to enhance scientific literacy, as well as public support for science—the two objectives go together. But for these efforts to be fruitful there must be intensive and extensive contacts at the grassroots. Organizations such as the Committees of Correspondence have the experience and the expertise to promote such contact.

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Lederman's report raises numerous interesting questions concerning the morale of scientists and the decline of the U.S. basic research base. His survey, however, does not recognize an inherent shift in the demographics of American education. Since 1969, college education has become an increasingly important prerequisite for increasingly lower level positions, which has resulted in a great increase in the student body of American colleges, fueled largely by an increase in the number of state-funded educational institutions. In fact, the number of private educational institutions has decreased since 1969.

This shift, which has created an increasingly large contingent of "marginal" undergraduates, has also created marginal universities staffed by marginal faculty members. The net effect of this growth in undergraduate education has been the acceptance of faculty (especially in science and engineering) who would otherwise have been relegated to junior colleges or high schools.

To insist that the federal research budget be expanded to support these marginal faculty at a level which equals that available to their more competent counterparts in the 1960s is mistaken. The U.S. scientific community needs to take a closer look at the mechanisms of funding, the quality of the peer-review system, and the overall impact of industry-sponsored research.

American research scientists need to develop closer working relationships with both industry and their peers. Lederman's concern over the cost of research equipment is well taken. The American research community can no longer allow the purchase of a $500,000 instrument that will be used at only 20 to 30% capacity. An instrument does not need to approach the cost of the Superconducting Super Collider to be considered for time-sharing arrangements.

The National Science Foundation's development of multidisciplinary centers demonstrates that university researchers can learn to share instruments, infrastructure, data, and industrial relationships. Continued efforts in these directions will lead to the resurgence of the American research community.

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Lederman discusses the increasing costs of scientific work—the "real costs" of more sophisticated equipment and the "bureaucratic accretion" costs, euphemistically referred to as "regulatory" and "overhead" costs. He also states the clear justification for maintaining a healthy scientific environment, which may be summarized as a listing of products and services that will ultimately appear as embodiments of the results of scientific work, which in turn will improve the quality and efficiency of our material world as well as "enhancing our culture by expanding our understanding of the universe and humanity's place in it."

U.S. government–funded science depends on the willingness and capability of a large body of individuals—U.S. taxpayers—to have some of their wealth sequestered and applied to the support of scientific research. The fact that the product of research is often intangible "knowledge" does not transform the economics. Scientific "knowledge" has costs to the creator, value to a user, and a price the user will pay, reflecting the user's judgment as to the added value that he, she, or the corporate "they" believe they can add in order to command a profit-making price. Giving it away, at no profit or for no equally valuable "payment in kind" to anyone or entity outside the United States is an outright economic loss to the U.S. economy.

In many cases, foreign corporations obtain the rights to U.S. technology by purchase of licenses or equity positions in U.S. companies. Typically, these U.S. companies are small, undercapitalized operations, working on product embodiments of technology originally developed at a nearby university. The costs of the products or processes "owned" by the company were only partially paid for by the shareholders of the company, while most were probably traceable to the university. Therefore, it is always relatively easy, and apparently profitable, to sell to the foreign purchaser property that someone else paid for.

One alternative, of course, is to emulate Japan. Stop the public funding of science and let big corporations do the work. Possibly, some other rich country will pick up the task of funding their universities and letting us buy the results or get them free from their published literature. Perhaps they'll run an "exchange" program to give away their know-how to us. Then we can do the commercialization based on foreign developments.

Or we could continue to support a publicly funded science effort, but classify its output as national property, not letting any information, or scientists, leave the country. This is pretty much what the Soviets did for many years, with less than enviable results.

Is there a "third path"? The Japanese system of cooperation among government, academia, and industry groups works well and ensures that scientific advances are communicated efficiently from the public institutions to industry (and do much to ensure that international flow is predominantly one-way).

The obligation to the public can be fulfilled in a variety of ways—the scientific entrepreneur who starts a U.S. company that converts academically derived know-how into a billion dollar enterprise is enriching himself or herself; by means of the corporation's and its employees' tax contributions, is repaying the U.S. public; and is in turn making it possible to fund successor generations of scientists.

The same result obtains where scientists, by means of patent license or other transfer mechanisms, enable existing U.S. companies to embody their knowledge into new products.

Ours is a free society, where accomplished scientists are free to emigrate or to sell their services, patents, or know-how anywhere in the world. However, all U.S. scientists who are concerned about declining public financial support should also contribute to correcting the problem. U.S. taxpayers cannot continue to be deprived of the return on investment necessary to replenish the funds used to support science. If they are, they will be either unable to contribute (as now seems to be the case) or unwilling, on the basis of the judgment that other uses of tax money offer better returns.

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There are so many ambiguities and unstated assumptions in the content of the personal essay by the incoming President that it is incumbent upon the AAAS now to encourage vigorous debate from all quarters on this document. I will try to clarify the issues by framing them as a series of questions.

1) Why is the equation of science = physics + chemistry + biology (the "PCB" exaggeration) permeating a document and the "informal survey" (all except one person cited is a professor of P, C, or B)? How can an association with deep roots in the geological sciences and its 16 other sections countenance this? What is AAAS' definition of "science"?

2) How can one report on the health of U.S. "science" without a passing analysis of what's happening in industry and government, where most American scientists work?

3) Why is "50% of academic researchers in 30 universities" "experiencing serious difficulty" defined as a crisis? What should that percentage be in a healthy situation?

4) By what moral standard can the universities that have increased their funding from $8 billion to $14 billion from 1979 to 1989, their numbers of researchers by 23%, and their per capita funding by 59% (*1*) keep on demanding generous and increasing funding for anyone they choose to put on the payroll (while infrastructure, health, and education are being severely cut)?

5) In light of the Ortega hypothesis about the minority of any profession who do the really creative work (*2*), what is the evidence that capping the number of departments and researchers at, say, 75% of the present level and supporting them longer at a higher level, would not solve *all* the problems reported (recent studies by the Institute for Scientific Information of citations of papers give little reason to doubt Ortega)?

6) Did no researcher identify factors internal to science, not connected to dollar amounts, as a cause for distress? Did not one comment on the wasteful, uniquely American system for disbursing funds, which consumes 33 to 50% of the time of scientists? Why haven't these scientists invented a more efficient system for themselves, when even the automobile industry has improved its gas mileage efficiency over 50%?

7) Was any literature survey done before repeating the "shortfall" figures? If so, why is there no reference to the study by the Office of Technology Assessment (*3*), to the debunking of the shortfall myth by A. Fechter (*4*), or to the report by the American Association of Engineering Societies (*5*)?

8) Why, if the German and Japanese dollar amounts spent on nondefense research and development are compared with those of the United States, are not the ratios of scientists to engineers or of science funds to technology funds also compared? These numbers are 300 to 700% higher in the United States. Indeed this is the key in a zero-sum game to improving our economic performance. Rebalance the distribution strongly (by factors of 2 to 5) toward S^2 science from S^3 science over a 10-year period [I define "S^2 science" as science for society (public and private sector) and "S^3 science" as *s*cience for *s*elf and *s*cience]. Both are honorable callings, but the public's responsibility for each is surely different. Many more personnel now doing S^3 science could, as they did in building the Bomb, move over to S^2 science and no doubt make equally great scientific contributions.

9) Why in connecting science to economic health does PCB science suddenly take a backseat to "the fruits of scientific research," and science (only here) suddenly become linked to technology? How can general claims that "science pays" "extensive returns to the economy generated by expenditures on science and technology" be made when the evidence shows no connection of any benefit to the nation which pays for S^3 science and its own economic prosperity? [Again, there is no reference to very relevant literature (*6*, p. 65, figure 19).]

10) Why in a market-oriented economy where everything else is privatized is it not recommended that true discipline-based S^3 science with no *discernible* value to, or market pull from, society increasingly be supported by private philanthropy? The gain in freedom to science would be undeniable, and perhaps a whole new era of new science, not necessarily dependent on enormous complexity or on huge ongoing machines, could be started. That would be a revolution for science—much more thought, many fewer proposals, and less reliance on machines—a really new frontier.

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REFERENCES

1. R. White, presidential address, National Academy of Engineering, October 1990.
2. J. Ortega y Gasset, *Revolt of the Masses* (Norton, New York, 1932).
3. Office of Technology Assessment, *Evaluating Scientists and Engineers* (Government Printing Office, Washington, DC, 1988).
4. A. Fechter, *The Bridge* **20** (no. 2), 16 (fall 1990).
5. *Eng. Manpower Bull. no. 105 (1991).*
6. "Background Report no. 3" (Congressional Research Service Series S, Washington, DC, September 1986).

Response: Jonathan Katz is not alone among scientists who would drown with a smile, the life preserver within reach but ignored because his hand tightly clenches the beard of his colleague-enemy. Just get those evil big scientists, those rapacious middle scientists, those cruel centrists and mini-emperors and the meek will inherit all the grants! One would expect a grander vision from scientists than one sees in the ultranationalism of the Balkans and the Middle East, but this may be too much idealism. Just plain political good sense should indicate that science, to advance, must present a united front with mutual respect for colleagues who work in diverse ways. A rational balance between shared facilities, interdisciplinary centers, and the individual investigators will probably be very difficult to achieve, but it will be far easier in an environment in which the total budget for science is adequate enough to allow good science to be pursued everywhere. There is terrible sorrow here. It is indeed difficult to avoid the road from frustration to bitterness to irrationality.

Craig Loehle worries about too many Ph.D.'s, but his exponentiating argument has clearly not produced this glut in the past 30 or so years, just for the reasons he cites—the demand for scientists outside of academia. The unemployment rate among scientists is under 2% according to the 1989 indicators (*1*) but, more significantly, many more must settle for second- or third-choice jobs. However, one can hardly say that in 1991 there is a glut of Ph.D.'s. In some fields there are shortages, and if it weren't for immigrants, the shortages would be more severe and more wide-ranging. In fact, with a large retirement bulge facing us, a changed demographics, and a "pipeline" effect that reveals a turning away from science of American children, many experts are predicting a severe shortage appearing over the next 15 or so years. In any case, our report was intended to warn of a potential danger to the research capability of the nation by sampling the mood of the successful researchers. To risk the future of this capability *because* of the possible Ph.D. glut would seem not to be very logical. Universities could in fact raise graduate school admission standards or tilt science students toward teaching, law, and politics (we could have three Ph.D.'s in our Congress!) if such an unlikely glut threatened.

Sandy Harcout says U.S. scientists are better off than most and he is surely correct; I could not articulate his conclusions any better, but then, an anthropologist is trained to the broad vision.

Stanley Weinberg also says it better; the number one suggestion of my report to the AAAS was exactly what Weinberg stresses—the need to reach the general public. His Committees of Correspondence is a great idea! AAAS should take note.

David Enolf raises a very important point that concerns many in this wide-ranging discussion: How many research universities? Can we be more efficient? (Contrast his praise of sharing facilities with our first respondent. Does Enolf have a beard?) I think these issues must be studied, but I tend to favor universities in geographically deprived areas getting into research, even at the expense of efficiency. Again it is a balance question, but diversity spreads the net wider and, since scientific creativity is still essential and still a rare, fluctuation phenomonon, the increased interest in science across the land must be beneficial. Over and over we have seen our great scientists spring from surprising places.

Nathaniel Brenner raises an issue about which our report had some arm-waving comments. Clearly the traditional way the products of research find their way into social and commercial use must be modified in these days of intense technological competition. I agree completely with Brenner's conclusions, as well as his incisive outline of the issues in insuring a return to the U.S. economy of the research investment. It is for issues like this that we proposed a commission. One confusing (to me) variable in all of this is the impact of the increasingly global nature of the research-technology spiral. With U.S.–owned companies doing research in France and Japanese companies in Princeton, the national boundaries seem increasingly porous to the conventional factors related to economic competitiveness. I am impressed by economist Robert Reich's argument (*2*) that what remains inherently national is the brainpower of the science-literate work force.

Rustum Roy's ten questions are more polemic than debate. I'll try a few of these. Question 1: Our survey, it was carefully explained, was a subjective sampling from the best-supported fields in the best-supported universities. Since then we have been inundated by letters from anthropologists, geologists, and zoologists saying in effect that they are just as badly off as the physicists and chemists. In fact, a careful reading would indicate that our conclusions and the concerns we raised were on behalf of *all* of academic science, as befits the AAAS.

The second question has to do with the fact that we concentrated on academic science. Again, the report says on page 3, "I recognize that I have focused narrowly on one sector of the research community and good science policy will require that any solution must also consider non-academic research. . . ."

Question 3 is a simple one—we used an unprofessional sampling technique. We sampled 50 universities, all receiving high levels of federal support. We sampled the most successful scientists. The results are stated in the report to the AAAS. Roy is not convinced. I am. I'd like to use this space to stress again that our concern is not the unhappiness of scientists; like a deep, resonant cough, the troubles of our best scientists are a symptom or at the least raise a question about the state of health of academic science.

I'll delete the fourth point, since "moral rights" are outside my domain of expertise. The fifth question about citationless papers is adequately debunked by the letters in *Science* of 22 March (p. 1408), especially that of David Pendlebury. I must confess to grudging admiration for the reference to Ortega. My weak counter is a paraphrase of a recently discovered manuscript sometimes attributed to Anaximenes: "Science advances along a broad front with occasional salients deep into the unknown." Roy clearly has nothing but contempt for the work of his colleagues who do basic research, which he deems worthless. The sixth question stumps me, but we didn't cover this in the course. The seventh question has to do with an ongoing debate that pits, in my view, simple projections of work-force demographics against complex, market-force arguments. Again, a reading of our report would reveal that we accepted the uncertainties in the projections but noted that prudence, in the light of new requirements for science and technology personnel, would call for keeping the pipeline filled [as, in fact the Office of Technology Assessment urges in its report *Federal Funding of Research: Decisions for a Decade* (*3*)]. The debunking of the shortfall myth by A. Fechter was in turn addressed by Peter House in the same reference given by Roy. The mind boggles at "questions" 8, 9, and 10. I hope I get a C!

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REFERENCES

1. National Science Board, *Science & Engineering Indicators—1989* (Government Printing Office, Washington, DC, 1989).
2. R. Reich, *Atlantic* **267**, 35 (February 1991).
3. Office of Technology Assessment, *Federal Funding of Research: Decisions for a Decade* (Government Printing Office, Washington, DC, 1991).

B Meson Lifetime

Please allow me comment on Gary Taubes' interesting and informative article about B factories (News & Comment, 22 Mar., p. 1419) recalling important results from B physics. The MAC Collaboration at the Stanford Linear Accelerator published the first measurement of the B meson lifetime (*1*). The publication alluded to by Taubes (*2*) (the MARK II experiment) came later, confirming the surprisingly long lifetime reported by MAC.

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REFERENCES

1. E. Fernandez *et al.*, *Phys. Rev. Lett.* **51**, 1022 (1983).
2. N. S. Lockyer *et al.*, *ibid.*, p. 1316.

Erratum: In the report "Isolation of sequences that span the fragile X and identification of a fragile X-related CpG island" by D. Heitz *et al.* (8 Mar., p. 1236), in the first line of figure 1 ("Chromosomal breakpoints"), PeCH should not have appeared. The breakpoint indicated corresponds to the APC5 cell line described by G. K. Suthers *et al.* [*Am. J. Hum. Genet.* **47**, 187 (1990)].

Erratum: In Constance Holden's News & Comment article "Kuwait's unjust deserts: Damage to its deserts" (8 Mar., p. 1175), the second sentence of the fifth paragraph should have read, "Any rock that has sat on the desert for a long time develops a shiny 'desert varnish' of light-absorbing manganese and iron oxides."

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