Policy Forum

This new feature for the exchange of opinion on issues of importance to the scientific community will appear from time to time. This first exchange resulted from a response to an editorial on the hazards of budget cutting ("Let Us Meander," 4 April).

Science Must Grow

LEON M. LEDERMAN

SCIENTISTS SHARE THE VERY HUMAN TRAIT OF REACTING TO austerity by trying to edge out the competition. One of the terrible consequences of the Gramm-Rudman-Hollings act is that it is beginning to set scientist against scientist. Recall the cartoon whose caption reads, "There is no meat, and we are fighting over the bones." I have witnessed the internecine warfare in Britain where fund-starved scientists bayed at one another over national television. The tone of the competition suggests the questions, How do we evaluate "big projects" versus "medium projects" versus "little projects"? How do we become more efficient? Implied is the additional contest, Social relevance versus abstract research. In his essay, Frank Press (Perspective, 21 March) suggests more peer review to increase the amount of science per dollar, which is fine, but his message is essentially pessimistic.

I, for one, feel no guilt at contributing to the national deficit—I wish I could do more. I would obviously be happier if there were no deficit, and I share with other citizens a respect for the awesome political problems of controlling the federal budget. However, if deficit reduction produces so destructive a result as now seems to hang over science, then we are clearly doing it wrong, and we must improve the procedure.

My field, high energy physics, is as remote from applications as you can get; nevertheless, it too contributes to a conclusion that science has always, and will always, be the best possible investment, next to education, that this nation can make in its future. I include here the social and humanistic sciences because when science creates new world views or the capacity for new technologies and new lifestyles, we will continue to need the wisdom these disciplines can contribute.

My suggested strategy is not to meander, as Koshland proposed, but to attack. What we need is a grand unification of science and scientists armed with the conviction that what is good for science is good for the nation. We scientists should marshal our forces, link arms, raise banners, and insist that science may be the last hope of humanity. The cycle of budget increases, slides, increases, and new preparations for drastic retrenchment is irresponsible. I will not catalog the tragedies of frustrated personal commitments. After all, these are hard times for all. I do feel outraged at the waste of economic and human resources, at the expenditure of huge sums to build new facilities, only to discover that we are too poor to use them. This kind of governmental bungling is inexcusable.

Efficiency? I believe that we are fantastically efficient already.

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Fight the Edifice Complex

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AMERICANS HAVE ALWAYS BEEN FASCINATED BY "BIGNESS," whether it takes the form of the biggest cattle ranch, the largest corporation, the tallest building, or the fastest airplane. American scientists are no exception: some fantasize about placing large manned space stations into permanent Earth orbit; others dream of building ever larger particle accelerators to smash matter into ever smaller pieces; still others yearn for commercial aircraft that can whisk them to Tokyo in 2 hours. When the pursuit of "bigness" becomes inordinate, when the costs of a particular project begin to defy a rational analysis of goals and priorities, when the value of an undertaking seems to lie principally in the size of its budget, one can be certain that an Edifice Complex has set in.

Senior officials of the federal agencies that support scientific and engineering research seem to be particularly affected by the Edifice Complex. They act as if funding increases and budgetary success for their programs can only be ensured by advocating massive projects or large machines. Yet, much of the creative research that is being done today—research producing discoveries of practical importance to societal needs—is being carried out in small university research groups that are victimized by the Edifice Complex.

In the small research group—typically composed of a professor, and students, and postdoctoral fellows or of a staff scientist and several technical assistants—individual initiative and creativity are highlighted. Students are given the opportunity to direct their own work and, more importantly, to take responsibility for the development of new ideas. The entire research group can change direction in the course of work without incurring large costs, thus providing greater flexibility and freedom for all members of the group. Healthy competition among and within groups confers the freedom and opportunity to break the bounds of limiting intellectual paradigms. In sum, the entire atmosphere of the small research group encourages new discovery.

The intellectual excitement and societal payoff of the discoveries made in small research groups are clearly illustrated in the recent report from the National Academy of Sciences, *Opportunities in Chemistry*. The intellectual vigor of chemistry, the quintessential small-group science, has never been greater. In the last two decades we have seen major advances in the synthesis of new substances and materials, including ultrapure semiconductors, pharmaceuticals, and advanced polymer composites; in the measurement and basic theory of molecular-level interactions; and in the unraveling of the fundamental steps of biological processes. Chemistry has become the

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Where else can the government find 80-hour-a-week Ph.D.'s, capable, dedicated, and with so exemplary a track record? This is not to say that science is above critical self-examination. More competition? Of course! Pruning out of unproductive fields? Yes! Even more stringent peer review with no one excluded? Sure! However, we have more than fulfilled our social contract. A list collected from the past 86 years of the major accomplishments in advancing our scientific culture and in creating the means for a fulfilling life would overflow the pages of *Science*. We are approaching the end of the century. Let our picket signs proclaim that Newton, Maxwell, Einstein, and Fermi, their colleagues in the other disciplines and their students' students should be protected, in their science work, from the problems of Gramm-Rudman-Hollings. At century's end, our nation should have a celebration of science with all the big, medium, and small projects that can pass peer review. We need the supercollider, synchrotron light sources, and graduate fellowships.

Now how can there be a special pleading for science in view of the havoc that Gramm-Rudman-Hollings wreaks on so many worthwhile programs? Is it more important, we ask ourselves, to do exotic research than to care for the aged, have a school lunch program, and so on? There are many things this nation does—it collects taxes in a fundamentally fair but highly flawed system which, incidentally, permits about $100 billion worth of taxes to go uncollected every year. It supports social programs, education, a vast military program, farm prices, et cetera. It preserves and fosters military bases, water projects, bridges, and highways, whether they are needed or not, as part of the political process. We support poor nations and send huge sums to corrupt dictators. In short, as a nation, we do many things that are wise and many that are foolish, we do compassionate things and cynical things. In every category the scale of expenditures exceeds the sums that can influence science.

In a sane, rational world our government must set priorities so that the well-being of the nation is advanced. There must be a balance between immediate needs and long-term investment, at least if we believe in the future of the nation.

I have estimated that an increment of about $2 billion per year can saturate the most urgent requirements of all university-based research outside the military. This includes all of physics, astronomy, life sciences, chemistry, earth sciences, mathematics, oceanography, and yes, history and anthropology—and if I have forgotten something, add a billion. Even before the discovery of the deficit, our university-based research enterprise was foundering because of aging equipment and equally aging faculty, as a casual reader of the White House Science Council report on the state of our universities (the Packard-Bromley report) can ascertain. In the course of the next decade, a dramatic revitalization of our research institutions will bring economic benefits, a better life, and a cultural level that makes it dignified to have a better life.

The war is not easy to win because there is no enemy. The Administration supports science. I personally have never met a congressman who is opposed to science. To protect the nation from the error of a judgment-free process, which is at the heart of Gramm-Rudman-Hollings, we must be assertive, and we must believe in the value of science.

Rather than cry disaster, we must urge our science leaders to begin organizing us. We must mount a major, even unprecedented, political effort to defend the public, the citizens, and our children's children from the foolishness of the course that we seem to be taking. We must remind the government of the people that there is a human destiny, a golden age out there and that only science, most broadly interpreted, can lead us to it. Then we must explain the need for continuity and growth, however constrained. Finally we must convince the government of the people that the infrastructure can easily be damaged but is exceedingly difficult to repair. We must be prepared to work hard at this, cooperatively, for the benefit of the nation. To meekly accept the inevitability of a long period of austerity is a betrayal of the trust invested in us as priests and workers in the temple of science.

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central science for improving the efficiency of energy conversion, whether the energy source is combustion, photosynthesis, or photovoltaics; and chemistry is an integral part of any solution to our critical environmental problems. The benefits that chemical research have diffused so widely through our technological society, and that promise to maintain U.S. economic competitiveness in fields as diverse as biotechnology, advanced materials, and pharmaceuticals, are almost exclusively the achievements of small-group science.

All this is threatened by the Edifice Complex. Massive projects and large machines can result in federal programs whose emphases are distorted and whose priorities are muddied. For example, chemical fuels currently provide more than 90% of the nation's energy. This contribution is expected to continue into the next century, given a steady stream of new and improved technologies. Yet little more than 5% of the Department of Energy's budget for fundamental research programs under "energy supply" and "general science and research" supports basic research in chemistry and chemical engineering. As another example, it is generally agreed that using advanced polymers to reduce the weight of transportation vehicles could result in tremendous energy savings. Yet the existing material sciences program in the Department of Energy supports virtually no polymer chemistry or chemical engineering.

Chemistry, of course, is not the only vital science that must fight the Edifice Complex. Condensed-matter physicists who work primarily in small groups and whose research, for example, has contributed greatly to the understanding of semiconductors, vital to our high-technology industries, are worried that support for small-group physics will be eclipsed by the proposed superconducting supercollider.

Of course, modern research requires support instrumentation, and to a lay person, that equipment seems expensive. But in chemistry and other small-group sciences the word expensive carries a different meaning than it does in, say, space exploration. A space station costs billions of dollars, whereas state-of-the-art instrumentation for chemistry typically costs a few hundred thousand dollars.

The national interest dictates that we act with special care to nurture small-group science. Federal programs supporting the small research group are less visible than massive projects or installations. Consequently, they are rarely the beneficiary of budgetary largesse and more often present an attractive target if an agency budget must be cut. The criterion for the federal government's investment in research should be the intellectual and societal importance of each research group's contributions. The public, federal agencies, and Congress must rediscover that the value of basic research lies not in its size and glamour, but in its ability to advance our understanding of nature and sustain our national competitiveness. The current vigor and promise of small-group sciences and their potential for contributing to our national well-being are too great to sacrifice on the altar of a national complex.