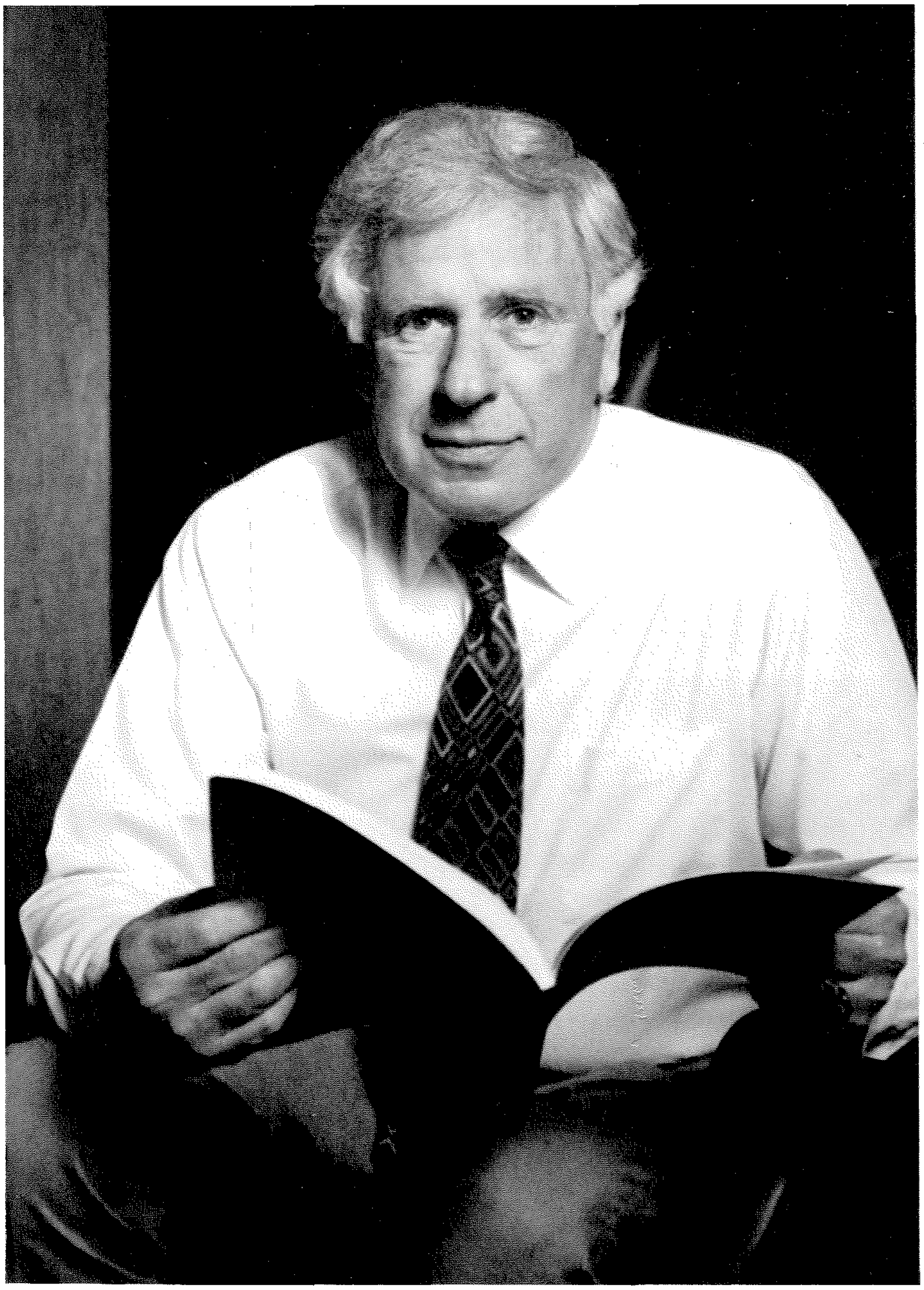

President Goldberger, who delivered this address to the Commonwealth Club of California in San Francisco March 13, will become director of the Institute for Advanced Study at Princeton in September. He has been president of Caltech since 1978.

What's Right,

by Marvin L. Goldberger

There is a widespread confidence in our country today about the contributions of science to the nation's well-being. Yet despite examples at every hand of a sustained commitment to American science, important issues of public science policy remain unresolved — problems that must be faced and solved if science is to meet these high expectations.

The present mood of scientific exuberance is easy to read. One example is the recent announcement of administration support for plans to proceed with the Superconducting Supercollider. This $5- to $6-billion project would create the world's largest and most powerful particle accelerator, designed to study interactions among elementary particles at energies never approached before.

Why should we undertake this project? Will it improve our economic comptetitiveness? Will it help our national security? Will the effort impoverish the rest of science? The answers to these questions are not easy to come by, but basically the answer to all of them is "no."

Indeed, there surely will be technological spin-offs that will be important in industry and defense. The real reason for the enormous investment is the drive to understand the fundamental forces of nature and the particles of which the whole universe is built. Must we, the United States, make this great expenditure? We are the richest country in the world. The field of high-energy physics is the most fundamental in all of science. As a nation, we cannot settle for anything less than the very best in all major scientific endeavors. We can, we should, we must take this giant step in the human endeavor to solve the mysteries of the universe.

The Superconducting Supercollider is not

What's Wrong with U.S. Science?

the only evidence of national confidence in science. Although the bulk of funding for U.S. science comes from the federal government, private sector support of academic research in science and engineering is strong — from corporations, foundations, and individuals. At Caltech, we have been exceedingly fortunate to receive two recent major gifts for needed research facilities. The first, for the Keck Observatory, with the largest optical telescope in the world, totals $70 million from the W.M. Keck Foundation. The second, a gift from the Arnold and Mabel Beckman Foundation, will supply $50 million for the creation and operation of the Beckman Institute on our campus, where scientists will attack problems at the interface of biology and chemistry.

Such huge contributions are the exceptions, of course. Nevertheless there is an important role being played by a few foundations and individuals in providing the crucial seed money for areas of science not sufficiently well developed to attract the attention of the federal funding agencies.

For example, at Caltech the research group led by Leroy Hood, the Ethel Wilson Bowles and Robert Bowles Professor of Biology, wanted to build a family of microchemical machines to analyze and sequence DNA and proteins. The National Institutes of Health and the National Science Foundation wouldn't touch the project. But a local Los Angeles foundation, the Weingart Foundation, provided about $1.5 million over five years, to get the program successfully off the ground. Now NIH and NSF money is available for this research. These machines and their lineal descendants will make the widely discussed program to sequence the human genome a realistic project in the foreseeable future. This kind of involvement in research by private foundations is a peculiarly American phenomenon.

Another increasingly important source of scientific research funding in universities is provided by corporations — sometimes in the form of general unrestricted contributions, but more frequently in the establishment of specific research relationships. About 15 to 20 percent of all research support at Caltech comes from industry. The relationships range from corporate funding for specific research projects of interest to the particular firms (and to us) all the way to broad involvements with several companies — who may even be commercial competitors — in generic research areas of interest to all the partners.

Having industry and the universities working together in these different ways has obvious benefits for both parties. The academic community — faculty and students — learns about the real world; and the industries involved are in an improved position to capitalize on innovative research that they may not be able to carry out in their own laboratories. It is entirely a win-win situation with only two caveats: Both sides must be diligent to ensure that the academic enterprise is not skewed by sponsor pressures, and adequate attention has to be paid to industry's ultimate need to show a profit — broadly interpreted — from its investment.

What can industry realistically expect from academic research? Basic research is, of course, the necessary underpinning of all our technological industries. The familiar examples of the transistor, the laser, and integrated circuits began as pure research endeavors. But much of what is troubling the country right now depends far more heavily on rather more mundane factors like management, systems engineering, and the quality of work life. We must be careful not to allow the research universities to be diverted toward short-range goals and away from what they do best: educating first-rate scientists and expanding scientific knowledge. The payoff from these "products" is hard to quantify, but if history is any guide, they are a good investment for both public and private funds.

Although science is obviously flourishing in America and public support is strong, there are some worrisome problems on the horizon that could pose long-term threats. One such problem that has received a great deal of attention lately is the pre-college preparation of our future scientists and engineers. Three recent studies compare mathematics teaching in the U.S. to that in other countries. They all show that our students lag far behind the students in other developed countries, particularly in Japan. Some of the gap can be explained by the difference between the teaching of math in the U.S. and elsewhere, but the greater involvement of parents in other countries with their children's education is also an important part of the explanation.

The organization of scientific research in the U.S. is the key. The co-location of research and teaching in our universities enables the scientific enterprise to flourish.

The teaching of science in our elementary schools ranges from nonexistent to execrable. Two Caltech professors, appalled at what their children were being taught, are developing a kindergarten-through-fifth-grade curriculum in collaboration with the Pasadena school system, and some 30 other faculty and Jet Propulsion Laboratory employees have volunteered to help. This is something universities everywhere must do. Science and math teaching in high schools is not much better; there are many high schools in the country where only one year of science is available.

One reason for the general decline in the quality of our elementary schools and high schools, and particularly in the quantity and quality of science there, is a shortage of qualified teachers. People who used to choose teaching as a profession can find less harrowing, more satisfying, and more lucrative careers elsewhere. People with mathematical and scientific training are in tremendous demand in technology-based industries. It is vital for the country that the investment be made — however it has to be made — to get good teachers back into the schools. As academic fundraisers always say: If you think education is expensive, consider the cost of ignorance. What is so unfortunate about the poverty of good science instruction in the schools is that so many of the potential Lawrences, Alvarezes, Panofskys, Einsteins, and Fermis never get turned on and never try to become scientists. What a loss; many of them become lawyers!

There is another and perhaps even more important consequence of the problem. Almost all the serious issues before this country have a strong scientific and technical component: energy, nuclear power, the environment, food, drugs, AIDS, national security, to name only a few. To make the decisions on such critical questions we rely on our elected representatives, who ordinarily have almost no scientific training to give them a basis for sound judgment. I am not advocating that everyone including our lawmakers should be a theoretical physicist. But we must have an educational system that will at the very least produce a population with a modest degree of scientific literacy.

Public policy toward pre-college education is inconsistent. On the federal level, there were severe cutbacks in the National Science Foundation's pre-college programs in the early years of the current administration. Under the leadership of director Erich Bloch, the NSF has worked to have some cuts restored — the adaptation for high school use of Caltech's video course in physics, "The Mechanical Universe," is an example. But the studies I cited show how much more needs to be done — in and out of school.

These things having been said, you may wonder why the United States has been able to become the best in the world in almost every area of science. How can this be when our schools are so bad? There are a number of reasons: We have a large and diverse population. The success of the scientific enterprise depends heavily on the contributions of a relatively small number of spectacular individuals. We have had and continue to have an enormous infusion of foreign talent, beginning with those who fled European tyrannies before World War II. We didn't have much competition for a very long time. It took western Europe, the Soviet Union, and Japan quite a while to recover from the war.

But our real secret weapon is something else. The organization of scientific research in the U.S. is the key. The co-location of research and teaching in our universities enables the scientific enterprise to flourish. This is what allows us to take college undergraduates who may have an educational history inferior in every respect to that of their foreign counterparts and turn them into the world's greatest, most productive, and most creative graduate students and scientists.

Other countries have created research institutions that do no teaching and universities that do little or no research — a system fundamentally flawed in my opinion, one poorly positioned to keep up with today's rate of scientific progress. I'm absolutely convinced that it is the concentration of roughly 75 percent of our basic research establishment in the universities that provides the explanation for U.S. science to which I now turn.

American academic science since World War II has become increasingly dependent on the fluctuating financial support of the federal government. Caltech and MIT, heavily research-oriented universities, derive more than one-half of their income from the federal treasury. I have several concerns about that relationship.

While the overall dollar amounts devoted to research and development have consistently reflected the confidence in science of the current administration, those budgets also have been increasingly skewed toward defense applications. For 15 years, from the mid-1960s to 1980, there was rough funding parity between civilian and military R&D efforts. Since then the balance has shifted heavily toward the defense side. At present, only a little more than a quarter of the federal R&D effort goes into what is primarily civilian research. And even the proportion of military R&D funding devoted to basic research has been declining since 1971. Outside of the Innovative Science and Technology Office of the Strategic Defense Initiative organization, much of the military R&D effort is focused on fairly short-range development efforts.

Another worrisome point: Federal tax reform, while overdue and no doubt on balance good for the country, in its present form will have a strong negative impact on research universities. Taxing our students' scholarships and fellowships appears to those of us in higher education to be especially counterproductive. At the same time, the revised tax law also lessens for some people the appeal of charitable contributions to higher education — and to other worthy non-profit organizations. Finally, the new law places severe restrictions on the use, by private but not public institutions, of tax-exempt bonds to finance construction of needed research, education, and support facilities.

Our students are not only going to be paying taxes on the aid they receive but also getting less of it. Again this year, in its proposed budget for the 1988 fiscal year, the administration recommends severe cutbacks in federal financial aid for students. The higher education community will no doubt turn to the Congress and lobby heavily for the protection of our current and future students. It is important to remember that there is a huge constituency: 12 million students (most with two parents) and 3,000 colleges and universities with interested faculty members.

American academic science since World War II has become increasingly dependent on the fluctuating financial support of the federal government.

When it recruits incoming freshmen, Caltech looks for the very best potential scientists and engineers without regard to their financial need. We're generally pretty successful in our recruiting — typically our freshmen have the highest average combined SAT scores in the nation. But we also find that 70 to 75 percent of our incoming students need financial aid.

We're trying hard to attract scholarship, fellowship, and loan funds from the private sector. But major reductions in federal financial aid programs might well turn Caltech and many other private institutions into places filled with only the children of the wealthy and the very poor; the middle class will not be represented. This is clearly wrong for the students, for the scientific endeavor, and for the country.

Pork-barrel politics has recently entered the halls of academe. In the past two or three years, it has become an all too common practice to hire a Washington lobbyist to present an institution's well-intentioned case for needed campus facilities. Such a practice, it is claimed, permits the "have nots" to play catch-up with the "haves." Although the needs for research facilities and instrumentation are very real on both "have" and "have-not" campuses, in my view pork-barrel politics is not the way to produce the kind of science this country requires.

To build a wall around our laboratories may serve to preserve the present — but only at the expense of the future.

With regard to needs for up-to-date instrumentation on campuses, let me give an example. About two years ago the Department of Defense asked the universities to make proposals for instrumentation in connection with potential DOD-supported projects. The department got back requests for $645 million; there was only $30 million to disperse. Quite a descrepancy. People have estimated a need throughout the country for about $2 billion to truly modernize university laboratories.

I'd also like to address, admittedly from a partisan point of view, the problems confronting one specific area of science, the unmanned exploration of space. My duties at Caltech happily include supervision of the Jet Propulsion Laboratory, which is operated by our institution on behalf of NASA. JPL and the other NASA centers involved in unmanned space exploration have compiled an impressive record since the orbiting of the first American satellite, Explorer 1, in 1958.

Even before the tragic Challenger accident, the competition for resources with manned spaceflight and military applications had placed major limitations on unmanned, scientific missions. The Challenger accident has, of course, compounded the problem. I cannot minimize the fact that our space science program is in very serious trouble — and was even before the Challenger disaster. Overemphasis on manned space flight, total reliance on the shuttle, the enormous cost of the space station, and the absence of a clear commitment to science has threatened our pre-eminent position.

Finally, I want to touch on the need for continued freedom in scientific communication. The trend toward placing an increased percentage of federal support of science within the defense budget has led to increased pressure to restrict the academic tradition of open communication. Again, that is certainly not the way to assure America's role as a productive source of high-quality science. To build a wall around our laboratories may serve to preserve the present — but only at the expense of the future. The real answer in science is to run faster.

"Competitiveness" is the magic word in Washington these days. Commenting on the importance of science and technology in a competitive society, Erich Bloch said: "We depend, for economic progress, on what we call the engineering and science base— the collection of people, institutions, equipment, and facilities that enable us to do fundamental research in the sciences and engineering. This dependence is real. So it is surprising that the United States is still not doing a very good job of taking care of the science and engineering base: We aren't training enough young scientists and engineers, we aren't investing sufficiently in research equipment and facilities, and we aren't supporting adequately the activities of our basic researchers."

American science is doing great things, but it does need increased support. This point was succinctly stated last year by the White House Science Council's Panel on the Health of U.S. Colleges and Universities: "One conclusion is clear: Our universities today simply cannot respond to society's expectations for them or discharge their national responsibilities in research and education without substantially increased support."

What's right about U.S. science plays a major factor in America's success, today and tomorrow. Let's continue to address what's wrong — or, perhaps more accurately, what can be improved — in the way we encourage and support scientific research. □