the problems of development in the Third World.

If, say, 5 percent of our scientific community were working directly on solutions to problems of the Third World, and if this 5 percent had the backing of the remaining 95 percent and the financial help of our governments and institutions, I am sure that the results would be extraordinary. Furthermore, our colleagues in the developing countries would be so stimulated and encouraged that their governments would be more willing to create and sustain their scientific and technological infrastructures.

The existing barriers between us would then become frontiers, which could be crossed at all points, in both ways.

Reference

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Science and Industry

Allan R. Crawford

Summary. Industry is concerned with basic science as the source of its technology, as the force of its philosophy of deductive thought, as its eye to the future, and as the impetus it provides for industrial innovation. Industry's strengthened advocacy of the support of basic science is essential for its future growth.

The views I present in this article on science and industry are those of a North American industrialist. My industrial experience has included the building of companies based on physics-related knowledge. Some of the companies have been concerned with the supply of investigative tools to the scientific community. I am a user of science and a supplier to scientists, as well as an observer of the scientific community.

Let me begin by defining science and industry. Science to me is the acquisition of knowledge of nature through the methods of proof or disproof. That acquisition of knowledge involves the reduction of complex phenomena to simple, elegant rules of action. Industry in a broad sense is the systematic use of knowledge and energy in the transformation of materials of low intrinsic usefulness (or value) into materials of a higher degree of usefulness (or value). Thus increased knowledge holds the key to increased industrial efficiency, and science is a basic contributor to this efficiency.

If one reflects on what was written of the industrial experience at the turn of the century, one finds that the thinking of such people as Henry Ford, although revolutionary at the time, is quaint by our standards. However, modern day industrial thinking directly parallels that of scientific thinking. The knowledge-based industry of today uses the same tools of deductive thinking and inference as are used by the scientist. Applied research, product development and manufacture, and quality control all require the same kind of problem-solving that is required of practicing scientists. Thus it is no accident that increasing numbers of knowledge-based industries are directed by managers recruited from the ranks of scientists.

It is tempting to argue that, given the similarities between science and industry, it is feasible and efficient to "mission-orient" and force the industrial application of science. This is a favorite government position, and notable successes with this approach were achieved in the space program and defense program. However, companies using this approach have fallen prey to two key factors of the industrial equation—market and timing. Several excellent initiatives, such as the Concorde, Hovercraft, and video phone, have failed in their stated goals simply because the market or the timing was wrong.

In my view, modern industry has a particular responsibility to be an advocate and sponsor of basic research. In the knowledge-based industrial sector, we have a situation that is largely technology driven, where many products, such as semiconductors and computers, are technically obsolete in 4 to 5 years. This contrasts with a product life cycle of 20 or more years in industry in the early part of this century. If we assume that the cost of research to replace a product remains constant, the yearly increase in research and development funding to effect a replacement is now four times as high. At least as important as the financial stakes are the constraints on judgment. If the wrong decision is made there is only one fourth of the time to catch up with the next product generation.

This has several important consequences. First, if industry is to stay competitive from product generation to generation it must be aware of, have access to, and use the results of both applied and basic science. Second, there will be more chance of success if the industrial planner utilizes the deductive principles that have served as the base of basic science. Third, the industrial world has many examples of industries that have made the wrong development choice and have disappeared. North American industry needs not only its own current research endeavors to chart future direction but also the vision and independence of view provided by basic research.

It can be argued that since basic science generally is not proprietary to a nation or a company, why not simply let other societies do basic research and then put our money in applied science or technology? I have mentioned that industry needs the vision that basic science provides as well as the intellectual rigor of its discipline. In a very real sense, the thinking of the purist sets the foundation and opens the view to the future in a particular branch of knowledge. Without access to that view, today's knowledge-based industry would operate in isolation. A knowledge-based industry that depended on secondhand access to information would be courting failure.

It is increasingly evident that the strength of our industrial base and also

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0036-8075/81/0904-1076S01.00/0

our society depends largely on the actions of our government. Since I am a Canadian, I refer here to my own government. There has been a distressing consistency in the performance of the Canadian government in treating science as an art form to be patronized, rather than a fundamental constituent of national policy and, in turn, industrial policy. For the success we have had in continuing the present level of support for science we can thank the statesmanship and vision of a few key contributors who saw the fundamental importance of science—such people as C. J. Mackenzie, General McNaugton, and C. D. Howe.

You cannot turn basic science on and off at 5-year intervals without crippling it. Without strong basic science the odds of there being a representative, world-class industrial component 50 years from now are very slim. There is simply not an appreciation by our legislators of the fundamental importance of basic science in our industry, our nation, our society. Industry has a major responsibility to reverse this situation, to argue forcefully for the support of basic science as a necessary component of its continued health.

How can industry better support basic science? From an industrial perspective, two major considerations affect interrelations with basic science. These are first, the rate of commercial application of basic science, and second, the necessity for basic science to retain its independence and produce advances in scientific knowledge not influenced or biased by practical considerations or forcing factors. If basic science is to receive increased support, the funding mechanisms need to be structured in such a manner as to take into account both the delay time between basic science and its application and also protect the independence of basic science.

I believe that the universities of North America have provided an effective buffer between industry and government on the one hand and basic science on the other. The privately endowed universities of the United States are key players in the long-term consistent support of basic science, and the institutes associated with the privately endowed universities have been particularly effective as centers of development of basic science.

The funding mechanisms of universities and institutes have been government, foundations, and, to a lesser degree, industry. Industry's funding of basic science is now channeled through government as a reinvestment of tax dollars and through direct gifts. Industrial funding was generally the source of foundation capital in the first instance.

As long as government is the funnel through which most of the funding for basic science must pass, the time it takes for a wheel of the political process to make one turn gives me grave concern. In North America we have set 4 or 5 years as the period between elections, but we expect our elected representatives to adopt a 50-year view. Fortunately, both the United States and Canada have seen fit to establish granting agencies. Both the National Science Foundation in the United States and the Natural Science and Engineering Research Council in Canada are sufficiently detached from the legislative process to provide some protection of basic science, but these agencies still have to cope with the uncertainty of the short-term funding cycles of their respective government. In addition, this system of funding puts basic science in competition with applied science for the available funds.

Private foundations provide an alternative funding mechanism. They are largely a North American phenomenon. This funding mechanism to universities and institutes is compatible with the delay between basic science and its application, and to some degree it isolates the foundations from forcing factors that might otherwise prevent them from making choices favoring the funding of basic science. Foundations by and large are created by the previous results of industry and individual industrialists; they have the freedom to reward and support excellence; they are competitive with the government funding conduit and allow the support of ideas for their merit.

Industry has limited options in the funding conduit it can employ: (i) it can directly support research through funding to universities; (ii) it can allow government to be the funding conduit and try to influence the particular government's funding priorities; (iii) if it is big enough, it can fund its own research program.

There are two problems with these methods: (i) the time lag for the application of basic science cannot help but skew support in favor of applied science; (ii) there is no general mechanism for industries to pass current funds in aid of basic research through foundations.

What can be done? There is no simplistic answer, but I have two suggestions that may be worth considering—the first has purely a Canadian connotation, although its effect would be relevant in North America; the second is more general.

First, there are a number of privately endowed universities in the United States that have demonstrated an independence of action in the support of basic science. The funding for these universities to a large degree is either directly from or a derivative of industry. If we in Canada intend to share as partners in North America in the practice and rewards of science, then we should invest in that society as partners. At present there is no privately endowed university in Canada. The University of Toronto is the closest. If the ratio of our population to the rest of North America is a measure of our responsibility, then we in Canada should establish at least one privately endowed university of excellence. Industry has a prime responsibility as a pioneer in that endeavor.

Second, a vehicle is needed through which all industry can fund pure science. I suggest that we should establish a mechanism similar to foundations whereby the granting body is independent of individual control and where funding support by individual industry is encouraged. One method would be for individual industries to fund a foundation on an ongoing basis from current revenue. The tax treatment of the donor companies should be at least as favorable or preferably more favorable than the tax treatment afforded a company funding its own research and development activities. This obviously would decrease short-term tax revenue; however, the justification is twofold: society would have an alternative funding mechanism that would provide an adjunct to government in identifying and supporting excellence in basic science, and industry would be increasingly visible as a supporter of basic science.

This at least would be a start. It is not at all where we in industry should be. I believe that industry generally should be investing each year directly in the support of basic research because such investment is a fundamental component of industry's long-term health. It should also invest substantially more in research for its own selfish reasons. The effect would be a healthy improvement of the frontiers of science to the advantage of North American industry and society. If we in industry do not act as pioneers in this endeavor some other industrial society will, and we in our industry, in our nation, in our science, will have accomplished too little, too late.

Note

I thank David W. Rowat and Randall Johnston for their help in preparing this article.