Why Support Science?

Research and development activities in the U.S. represent a big enterprise, comprising about 2.5 percent of the nation's gross domestic product, according to data compiled by the National Science Foundation. This figure includes a significant amount of applied research and development performed by industry or for defense-related purposes. The amount devoted to basic knowledge-driven research is about 0.4 percent of GDP. The U.S. federal government appropriates about $17B per year for basic research 58 percent of the total), somewhat less than the percentage in Japan or Western Europe, according to NSF. On any scale, such large expenditures make it entirely reasonable to ask why society should support the scientific enterprise.

The motivations for science research vary from one field to another. Some research questions have immediate goals, clearly directed toward solving specific problems or addressing particular conditions in society. Much medical research, for example, focuses on finding answers to questions such as why cancer cells develop and how to inhibit their growth. Military research is also usually focussed, investigating for instance, the effect of strong bursts of electromagnetic energy on missile guidance systems. Materials science explores the properties of substances that make them useful in applications such as TV transmission, power distribution, or computer chip manufacture.

Other sciences pursue questions more distant from current everyday concerns: biochemists seek to understand how complex protein molecules 'fold' into their compact forms; astronomers attempt to discern whether the expanding universe will ever stop and recollapse; and high-energy physicists probe the forces and particles at the heart of all matter, at the smallest distance scales imaginable.

The justification for investigating questions whose answers have ready applications for society is straightforward. For example, we can estimate the human and social costs of diseases to determine the price we are willing to pay for cure or eradication. The excellent record of successes, over time, in these directed fields is apparent to us all.

Although the justification for more basic, non-application-directed research is harder to state, it exists nevertheless. It has three important components. First, when we think about the reasons for pursuing basic science, we must never underestimate the human desire to understand the world around us – not merely to acquire better control of the world, but to satisfy our yearning for understanding. Few of us are immune from the awe of gazing at a starry night, wondering how these distant suns came into being, and pondering the past and future story of the universe. Similarly, the question of what we find when we carve observable bits of matter into increasingly smaller pieces has been with us at least since the ancient Greeks. Asking questions like these is at the core of being human; one need only look at the themes of the poets, musicians and artists over the millennia to see that we are programmed to want to understand our world and its origins as thoroughly as we can.

We can also recognize a second very important aspect of basic research: it attracts intensely inquisitive and often unusually capable people. Such people may sometimes be dreamers, but they are also driven to find practical technical means to investigate the objects of their fascination. The quest to understand some basic aspect of nature often results in the creation of new practical and conceptual tools that didn't exist before the dreamer began investigating the problem. The investigators themselves may be indifferent to the applications of their tools beyond their own purposes, and sometimes they are not well equipped to explain what these tools might mean beyond their narrow spheres of application, but their legacy can be tremendous.

Third, we have come to understand that even though some science may seem wholly remote from the daily needs of society, in the long term esoteric new knowledge has the habit of re-entering the mainstream with a bang!

To take a few examples:

- The discovery that all matter and energy comes in discrete bundles was at the core of forefront research on quantum mechanics in the 1920s. This knowledge did not originally appear to have much connection to the way things were built or used in daily life. In time, however, the understanding of quantum mechanics allowed us to build devices such as the transistor and the laser. Our present-day electronic world, with computers, communications networks, medical technology, and space-age materials would be utterly impossible without the quantum revolution in the understanding of matter that occurred seven decades ago. But the payoff took time, and no one envisioned the enormous economic and social outcome at the time of the original research.

- In the late 19th century, physicists were surprised to observe that, contrary to all everyday experience, certain materials showed no resistance to the flow of electricity at very low temperatures. For decades, this phenomenon of superconductivity remained a curiosity of interest only to research physicists. Now, however, the actual and potential technological applications in the form of very high magnetic fields for magnetic resonance imaging diagnostics, the levitation of trains, and power transmission have already made a great impact on our world – and promise even greater impact in the near future.

- Research on making new, very large, organic molecules was once the preserve of chemists who were mainly interested in exploring to see what new configurations they could construct. But as the researchers became more adept at manipulating megamolecules, applications came into view, spawning the huge plastics and pharmaceutical industries whose developments influence all aspects of our everyday lives.

Besides the sometimes far-future applications of advances in basic knowledge, the tools used to carry out the research can themselves be found in surprising and general applications.

- All modern forms of medical imaging technologies had their beginnings as detection devices in physics and chemistry. Many of the industrial scientists who created such devices such as CAT (Computer Aided Tomography) scanners were originally young scientists trained within the basic science community.

- Parallel computing, the use of many computers to attack different parts of a problem simultaneously, was invented by scientists who needed to process their data faster than the conventional, one-processor mode could achieve. This computing method has transformed such diverse areas as weather forecasting and market trend analyses.

- The use of particle accelerators not only for the scientific study of the collisions that they produce but as technological tools, has become widespread. The synchrotron radiation emitted when charged particle beams bend has become an indispensable tool for the study of new materials and making 'pictures' of living cells. Some hospitals now even have their own accelerators for the therapeutic treatment of otherwise untreatable tumors.

- Are you reading this article on the World Wide Web? If so, you are directly benefiting from a tool that originated because of the need of large but far-flung scientific collaborations in particle physics to communicate quickly and effectively, worldwide. The Web, developed by the European high-energy physics laboratory CERN, has now transformed the way we find and use information, talk electronically to our friends, and view the events of the world. It is striking that the communications needs of a few thousand particle physicists should lead so quickly to so large a change in the way we live.

One should never bet against the most esoteric discoveries in the laboratory coming back to transform our society and repay the original investment many thousandfold.

Advances in one branch of science often stimulate fundamental advances in another. There is good reason to maintain a broad program of basic research, for the cross-fertilization among the many fields is huge. In exceptional cases, breakthrough discoveries may have wide effects in many fields. More often, however, newly developed techniques in one area find application in another, opening doors previously wedged shut against further advancement. The development of MRI as a powerful diagnostic tool for non-invasive imaging of the body is an example: it depended upon the discovery of the esoteric ‘spin’ property of the atomic nucleus in physics; on the discovery by chemists that the energy associated with the flip of this spin depends upon the chemical environment of the nucleus; on the development of powerful microprocessors by electrical engineers in industry; on the development of superconducting magnets for particle accelerators; and on the pattern recognition techniques pioneered in biology and particle physics.

This interconnectedness of science – and its worldwide basis for progress – prompted the heads of 106 scientific, engineering and mathematic societies to urge Congress in 1997 to provide increased support for basic research. It should be noted that Congress has heard and largely agreed with this point of view, giving basic science support by government a raised priority, even in a climate of reducing other activities.

Why, then should we as a society choose to support basic frontier research like that done at Fermilab? First, because we expect that from this research we will come closer to answering the fundamental questions that have intrigued humanity for all our history. Where do we come from, what are we made of, why is our world the way it is? Second, because we can be confident that, although we have little idea at present which advances from basic research will in time come back to transform our society, we have every historical reason to expect that the benefits will justify our investment manyfold.

Finally, participation in basic research will benefit society by educating and training thousands of students who will choose to enter the workforce not only in academic research but as workers in many diverse industries. Currently, there are more than 600 graduate students from universities around the world who will receive their Ph.D. degrees from their work at

Fermilab. Experience shows that only about one in five will stay in basic research. These young men and women who migrate to other fields are some of the most precious and unique 'products' of our research, paying back in unpredictable ways. These young scientists are the messengers, the people who carry novel and sometimes eccentric tools and ways of thinking into society at large, and who bring them to bear on the applications that benefit us all.

The argument for support of science is compelling. Those of us engaged in doing research have a strong obligation to share our aspirations, achievements – and sometimes failures – with our fellow citizens who support us, and continually look for better ways to bring the benefits of science to all.