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All Roads Lead to Rome

The old adage of the title has a parallel in the scientific world—"all research leads to biomedical advances." The fact that research in one discipline contributes to another is well understood by the scientific community. It is not, however, so clear to the public or to public policy-makers. Because public support for funding of biomedical research is strong, the scientific community could build a more effective case for public support of all science by articulating how research in other disciplines benefits biomedicine.

The time is ripe to improve public appreciation of science. A recent National Science Foundation survey suggested that Americans continue to support research expenditures. In addition, public opinion polls indicate that scientists and science leaders enjoy enviably high public esteem, second only to that accorded to physicians. Instead of lamenting the lack of public understanding of science, we can work to enhance public appreciation of scientific research by showing how investigations in many areas intertwine and contribute to biomedical advances. A crucial task is to convey to the public, in easily understood terms, the specific benefits and the overall good that result from research in all areas of science. For instance, the public may not fully understand the physical principles behind lasers, but it clearly can appreciate the extraordinary medical benefits resulting from this technology.

Take, for example, agricultural research. On the surface, it may appear to have made few significant contributions to biomedical advances, except those directly related to human nutrition. This view is incorrect, however. In the case of nutrition, the connections between agricultural and biomedical research are best exemplified by the vitamin discoveries. At the turn of the century, when the concept of vitamins had not yet surfaced and nutrition as a scientific discipline did not exist, it was in a department of agricultural chemistry that the first true demonstration of vitamins was made. Single-grain feeding experiments documented the roles of vitamins A and B and of nicotinic acid (niacin). The essential role of some minerals (iron, copper, and iodine) was shown later, and these discoveries provided the basis of modern human nutrition research.

Despite such direct links, however, it is the wondrously serendipitous discoveries that have been made in agricultural research that reveal its true importance to biomedicine. Life-saving antibiotics such as streptomycin were discovered in soil microorganisms. The first embryo transplant was made in a dairy cow, and related research led to advances in the understanding of human reproduction. Coumarin, extracted from moldy clover hay that caused cattle "bleed" disease, was the active ingredient in the first blood anticoagulant medicine used to treat heart problems (President Eisenhower's heart condition was treated with dicoumarol). In minute quantities, botulinum, a deadly food toxin, reduces muscle contraction and is effective in the treatment of dystonias, stuttering, and Parkinson's disease. The discovery of immunological tolerance in fraternal calf twins provided the basis for understanding and treatment of rejection in organ transplantation. And edible vaccines are being produced in seeds and plant parts that will, in the not-too-distant future, provide a source of inexpensive, highly transportable vaccines with long shelf lives.

Cowling *et al.** recently made a comparative analysis of agricultural and medical research in an attempt to document the aggregate return to society from each domain. Although these two areas of research substantially affect the quality of our lives, their linkages are not readily apparent. The contributions of specific scientific research to biomedical advances should certainly be emphasized, but a compelling case must also be made that all sciences, math, and engineering are inextricably interrelated and contribute to better health for us all. We need to work to convince the public that without advances in nonmedical fields, crucial advances in biomedicine will be severely hampered. After all, it is the totality of the science and technology enterprise that will provide the basis for a secure future, in medicine and in other areas of life.

Jaleh Daie and Roger Wyse

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*E. B. Cowling, J. T. Sigmon, C. E. Putman, *Issues in Science and Technology* 12, 29 (1996).