

that employment in Humboldt County will be down significantly by 1975 (4). It has been argued that tourism would more than compensate for the lower employment in logging. But not if the trees that the tourists come to see are gone. Why can't young and mature trees be harvested at a reasonable rate, the old trees saved, and both tourism and logging flourish?

The question posed earlier has been answered. Redwood growth and survival can be modeled, using matrix

methods in a new context. Meaningful conclusions may be drawn. And the results are sufficiently tantalizing to inspire further research.

References and Notes

1. "The Redwoods of California" (Resources Agency, Sacramento, Calif., 1964).
2. N. B. Drury, *Amer. Forests* 75, 24 (1969).
3. D. F. Roy, "Silvical Characteristics of Redwood (*Sequoia Sempervirens*)," *U.S. Forest Serv. Res. Pap. PSW-28* (1966).
4. W. Bronson, *How to Kill a Golden State* (Doubleday, Garden City, N.Y., 1968).
5. P. H. Leslie, *Biometrika* 33, 183 (1945); *ibid.* 35, 213 (1948).
6. N. A. Lewis, *Sankhyā* 6, 93 (1942).

7. L. P. Leffkovitch, *Biometrics* 21, 1 (1965).
8. E. C. Pielou, *An Introduction to Mathematical Ecology* (Wiley-Interscience, New York, 1969).
9. R. A. Frazer, W. T. Duncan, A. R. Collar, *Elementary Matrices and Some Applications to Dynamics and Differential Equations* (Cambridge Univ. Press, London, 1960).
10. I. S. Sokolnikoff and R. M. Redheffer, *Mathematics of Physics and Modern Engineering* (McGraw-Hill, New York, 1958).
11. R. Hartesveldt, Department of Biology, San Jose State College, private communication.
12. I thank Mrs. Madeline Bosch, the Save-the-Redwoods League and Mr. DeWitt, the Sierra Club and Mr. Robinson, Mr. Cramer Adams of the California Redwood Association, and Dr. Glenn Moffat of Foothill College, Los Altos Hills, California.

The General Scientific Association: A Bridge to Society at Large

William Bevan

A major concern of this meeting, as with many gatherings of scientists these days, is the apparent disaffection of society in its several segments from the scientific enterprise. Federal expenditures for scientific education and research have leveled off. The scientific community's influence in Washington has declined. Science graduates are experiencing difficulties in finding jobs for which they have been trained. Student interest has swung toward the humanities and toward the traditions of intuition and mysticism. The general public is apprehensive that science is responsible for many of our current environmental problems and fears that even greater untoward effects will follow in the wake of future scientific advances. Newspapers and magazines are replete with observations that some food additives appear to be toxic, that plastics have become hard-to-eliminate mountains of refuse, and that psychological principles are potential means of thought control.

Why the Problem?

There is a complex of reasons for this current state of affairs. First of all, it has resulted, in part, from certain long-in-

grained attitudes in the practice of science. Our emphasis on excellence in individual performance has fostered a psychology of elitism that has made both our enterprise and our body of knowledge esoteric and increasingly inaccessible to the layman at all levels of society. Where the artist has chosen to illuminate commonly shared truths, the scientist has chosen to become the master of the highly specialized fact and to proclaim its overriding importance. But the line between high priest and villain is often a fine one, and the public's deference has been tempered by distrust. The comic-strip stereotype of the mad (that is, evil) scientist still emerges from time to time in the layman's thinking about us.

Furthermore, we have persisted in the view that science is value-free, and we have displayed only minimal interest in the several uses of scientific knowledge and their consequences. But one need only observe the keen competition that exists among one's colleagues in the pursuit of discovery, or hear their anguished cries as the shifting of research funding follows the waxing and waning of particular fields, to hold suspect the widely proclaimed neutrality of science. Indeed, one need only compare the dis-

tribution of funds within the scientific community at any particular time to recognize that values influence the behavior of scientists.

Finally, the preoccupation with the primacy of creativity in individual investigations has prompted a circumscribed perception of the implications of one's scientific work and a tendency to ignore opportunities for research that bridges the free-ranging interests of basic science, on the one hand, and the practical requirements of technology, on the other. Just as we are inclined to denigrate the task of applying science, so we tend not to seek out fundamental problems in applied settings.

In addition, we scientists have failed to comprehend the significance of certain basic characteristics of individual and collective human behavior. People are apprehensive about things they don't understand, for they rightly perceive that they cannot control what they do not understand. Examples abound. One from a less emotionally charged era of several years back is the controversy over fluoridation. Just as the layman will fear things he does not understand, so will he be impatient with things he considers to be irrelevant. We may conjecture about the current diminution of public interest in space science. There is, of course, the tedium of essentially perfect precision. I suspect, however, that the real reason is reflected in the remark of a television personality who recently wondered aloud whether or not those moon rocks were all that important. But if the man in the street has been faced with an increasingly esoteric science, the lay leadership, particularly that at the federal level, has become

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increasingly knowledgeable about science, both as a body of information and as a social institution. Hence, the lay leadership has become increasingly more discriminating in its behavior toward scientific proposals. At last we are learning that human institutions, and particularly those of government, have multiple loyalties, and that to expect uncritical support on an indefinite basis is to be unrealistic.

Out of this lack of full mutual understanding have come some acute problems. One can select any of the major world problems that preoccupy us at present—the population explosion, weaponry, environmental pollution, social inequality, and so on—and argue that science has directly or indirectly aggravated each of them. Decisions to follow a particular course of scientific or technological development have typically been the prerogative of a comparatively small number of persons, and have been made after examining a relatively limited range of considerations. Thus, projects like the SST and ABM typically represent a sizable investment of time, talent, and funds before the wisdom of their continuation is ever challenged.

Furthermore, the past several years have seen a “crisis of expectation,” stemming from a difference in understanding between the scientific community and the lay leadership concerning the purpose behind much of our research funding. To the scientist, the moneys were a recognition of the virtue of all science; to the Congress and the White House, a commitment toward the solution of national problems. Thus, the President could ask where the cure for cancer was and the biomedical science community be caught up short.

But now that I have indulged in thumbnail philosophy, let me hasten to say that I believe our view of the situation is exaggerated. Our budgets, overall, have not been cut. Rather, there has been over the years, as I. I. Rabi has noted, a kind of scientific Parkinson's law: scientific activity will grow to meet any set budget and will find it grossly inadequate. It is natural for the bride, after a prolonged honeymoon, to overreact at what she senses to be the first signs of inattention. A bit of the romance must inevitably be lost when one settles down to the ordinary, daily routines of a marriage. On the other hand, what should be reassuring to the scientist is the fact that the lay public—institutions as well as individuals—recog-

nizes that the relationship between science and society at large is a permanent one. Despite the layman's apprehension about science, and his impatience with it, the demands of modern life allow him no alternative but to accommodate to it.

Resolving the Problem

The problem as I have sketched it—or at least those aspects of the problem that will require initiatives from the scientific community—may be summarized by the phrase, “a need to increase the public's understanding of science.” Its resolution, of course, is a many-faceted affair that will inevitably involve many agencies within our scientific community.

First, there is the need for an assessment of our own attitudes. We must recognize the interdependence of science and society. While scientific advances emerge from prior scientific knowledge, the framing of essential scientific questions often depends upon the specific intellectual setting provided by society. And at the level of application, solutions are never simply a matter of technical competence. For example, in India, where the social structure is matriarchal, the successful control of population will probably depend more on ways of providing for the social status and economic security of women in their advanced age than on anything else. But in seeking an accommodation with the forces of society at large, we cannot afford to abandon the perspective that links application to basic science. Balance in commitment, with all that it implies in individual rewards and reinforcement, is important for the future.

In communicating about science with the public, certain matters are important. Understanding will be facilitated if the fundamentally unitary nature of science is understood—if the layman can see the common elements of method embedded in the multiplicity of technique and be shown the implications of particular discoveries for a wide range of problems. Thus, it would be helpful, for example, if he understood better how the study of the chemistry of hemoglobin led to the identification of the cause of sickle-cell anemia, or how the study of control of the autonomic nervous system led first to the identification of chemical mediators and later to compounds successful in the treatment of Parkinson's disease and certain kinds of heart disease. Tim-

ing is extremely important. Major program proposals warrant discussion in the broadest possible fashion at the earliest possible time—at a time when problems can be resolved before issues are joined. The time to establish a commission on jet engine noise is when the first jet pod is mounted to an aircraft wing, not after the test-flight schedule of an SST has been planned. It is also important that the public have a better grasp of the time course typically required for successful application. Hugo Thiemann has estimated that the lag between idea and product is of the order of a decade or a decade and a half, and he sees no evidence that it will be shortened. But, most important of all, the public must learn to appreciate the fact that, given the state of the art at any particular time, the resolution of complex technological-social problems requires a strategy of accommodation. People inevitably must perceive that resolution is a matter of striking a balance of advantages and disadvantages in order to achieve a particular criterion of productivity or service. The power problem is a good example. Given agreement upon a national requirement for electric power, the next step is to perform the broadest possible sort of comparative study of fossil fuels and nuclear energy, as energy sources, making explicit the merits and the costs—economic, social, esthetic, and pollutional—of the several ways of achieving this goal.

AAAS and the Public Understanding of Science

I have been asked to address myself to the question of roles and responsibilities of scientific organizations like the American Association for the Advancement of Science in our changing world. My thesis, I am sure, has been clear throughout: It is that the special responsibility of organizations like the AAAS is both to interpret science to the larger society and to participate in assessing its consequences.

The purposes of the AAAS are stated in Article II of its constitution.

The objects of the American Association for the Advancement of Science are to further the work of scientists, to facilitate cooperation among them, to improve the effectiveness of science in the promotion of human welfare, and to increase public understanding and appreciation of the importance and promise of the methods of science in human progress.

These objectives have been part of the Association's constitution for many years, and, at least since 1951, the Association has taken its commitment to the application of science in the promotion of human welfare and to the improvement of the public understanding of science with increasing seriousness and diligence. At that time, the then Executive Committee of the AAAS Council met with a group of consultants at Arden House in New York to assess the functions of the Association. From that meeting came a statement which reaffirmed the responsibility of the Association in advancing public understanding of science. This has been a shibboleth for the Association ever since.

The AAAS possesses certain special qualifications for this role. Because it is a private, that is, nongovernmental, organization that sustains itself essentially with the dues it collects and the income it generates in its various activities, it is maximally free to stress the need to evaluate the alternative goals of society and to explore the relevance of science in the pursuit of these goals. Because it is large, because it includes distinguished scientists from across the full spectrum of science, and because it has formal ties with virtually all of the major scientific and technological societies in the nation, its actions can command attention and its exposition of views attract serious consideration. Because its membership includes persons holding a wide range of views on issues of interest and concern to scientists, the Association constitutes a forum for the airing of these views. *Science*, for some time, and the Annual Meetings, increasingly in recent years, have sought to exercise this function. Through its publications and meetings, and also through its committees and commissions, the Association has increasingly served as an information exchange and as a catalyst for action. And because of the range of talent and experience within its membership, it is peculiarly equipped to serve as a broker in the organization of commissions and other groups to perform analytical studies of both the technological and the social and political ingredients in significant problems of society, and as an agent in the identification of qualified consultants to consider these matters.

The AAAS has chosen five populations toward which to direct its efforts

to increase the public understanding of science: the scientific community itself; youth; teachers and educational administrators; leaders in government—now primarily federal but, in the future, local leaders as well; and science journalists.

Our oldest and most fully developed program in public understanding has been concerned with the education of scientists. Our major device has been *Science*, through four of its departments. Editorials are prepared on a wide assortment of timely questions by the editor, by the publisher, and by a number of outstanding persons, both scientists and nonscientists. Major articles are written on a wide range of currently lively topics. "News and Comment," begun in the late 1950's, deals in depth with policy issues of concern to scientists, and is perhaps the most widely read part of the magazine. We have recently begun a new feature called "Research Topics," which consists of in-depth reviews of the current state of knowledge on problems of basic scientific interest. Recent issues, for example, have included reviews of such topics as laser ranging and mercury in the environment. As we build staff for this activity, and as this staff interacts with the News and Comment staff, we shall be, in the language of the Arden House statement, increasingly capable of putting science back together.

The Annual Meeting has become, to a major degree, a commitment to public understanding. Programs are planned to serve the common interests of scientists from all segments of science and, in addition, to challenge the interest of the lay public, particularly those people in the city where the meetings are being held. In Chicago last December, we conducted some 290 half-day sessions with discussions, some formal, some informal, of such matters as "Mood, Behavior, and Drugs"; "Urbanization in Arid Lands"; "Automobile Pollution"; the "Economics of Pollution"; the "Role of Women in Science"; and "National and International Dimensions of Science Policy." Scientific sessions were supplemented by exhibits, tours, and films. And at the end of each day, an hour-long program over educational television summarized the highlights of the day's activities, as well as presenting an in-depth treatment of some major topic. We have just completed a preliminary analysis of responses to an extensive questionnaire concerning the Chicago

meeting. We find that, for the future, attendees most prefer symposia on topics of general scientific interest with social implications, such as "Mood, Behavior, and Drugs"; sessions on topics with broad science policy implications, such as "Reducing the Environmental Impact of a Growing Population"; and symposia on specialized topics, such as "Interstellar Molecules and Chemistry."

After some years without personnel to give their primary attention to the public information needs of the Association itself, we have begun to add staff for that purpose. Our first attention will be given to making the *AAAS Bulletin* a special means of communicating with the membership on Association and related affairs. But we have to find other media and styles of communication. Everyone is being engulfed by paper, and additional publications, no matter how attractive, run the risk of being lost in the welter of material now in circulation. We are exploring the adaptability of television techniques to our goals and have begun to issue audiotapes. These latter are sound recordings in cassette form of important addresses and panel discussions which have taken place at the Annual Meeting. We are most pleased and reassured by the volume of sales we are now experiencing from these tapes.

If we are to correct the impression that the scientist is somehow a different kind of person from the layman, we believe that we are most likely to succeed by familiarizing young people with the method and logic of science in a firsthand way. Thus it became the Association's view that science should be taught as a problem-solving activity, and not as a codified body of information. Accordingly, over the past 8 years, with the help of the National Science Foundation, the AAAS Commission on Science Education and its staff have developed *Science—A Process Approach*. This is a program for kindergarten through the sixth grade, which leads the child to understand science through looking at and dealing with the world in the same way that the scientist does. Beginning with very simple situations, the child observes, classifies, uses numbers, measures, communicates, predicts, infers, and ultimately formulates hypotheses and does simple experiments. In the process of these activities of the scientist, he incidentally acquires an impressive body of information that

now is functionally meaningful for him. At present, *Science—A Process Approach* is being used by well over 50,000 teachers throughout the country, with approximately 2 million children.

Each year, the Association also conducts the Holiday Science Lectures. These are 2 days of lecture and discussion which bring together a limited number of outstanding high school students and distinguished scientists who are also exciting teachers. This year, five series are being conducted—in Boston, Chicago, Fort Worth, Portland (Oregon), and Phoenix, respectively. For example, in Boston this April, Seymour Kety will discuss "Biochemistry and Mental State," and last December in Fort Worth, R. H. Bing talked about the "Inventive Side of Mathematics."

Last year the Board of Directors established a Youth Council, both as a means of recruiting young scientists into the affairs of the Association and as a step toward meeting its very real concern for the alienation of young people from science. Furthermore, the Committee on Public Understanding of Science now has under way four feasibility studies, all concerned with identifying more effective ways of communicating with youth about science.

A concern for youth, of course, also means an involvement with teachers and the educational system. In addition to having created *Science—A Process Approach*, the Department of Science Education of AAAS also prepares study guides, operates an information exchange, and conducts a wide range and variety of seminars and workshops on special topics for teachers at all levels. A special program of Chautauqua-type Seminars for College Teachers of Science will be offered next year in 12 cities across the country. A total of nine courses will be offered at each center. Seminars for school administrators on new developments in science and science education are also offered

regularly each year. Last year, the Association circulated almost 80,000 copies of an annotated bibliography entitled "Science for Society." This year, AAAS will bring out a new edition, which it further plans to update and enlarge on an annual basis. Cooperative activities have been established with the Regional Environmental Centers about the nation in order to provide support for their programs in environmental education.

The Association publishes a quarterly, *Science Books*, that contains short reviews of books in all branches of science, accompanied by a rating of quality and an indication of the audience—for example, junior high school students—at whom the book is primarily directed. This publication is supplemented by the *AAAS Science Booklist* and the *AAAS Science Booklist for Children*, hardcover compilations from *Science Books* that are put out in new editions every several years.

One new dimension that we will seek to add to our educational programs involves the concept of collegueship. We hope to establish working relationships between teachers and professional scientists who live in their communities. Through this means, we hope to provide teachers with technical support and, at the same time, a closer identity with the scientific enterprise.

Our program for government leaders to date has been rather limited. For those who read *Science* there is, of course, the News and Comment section, the editorials, and other materials. There are our symposium volumes, many of which have become standard references on problems of both technological and social significance. Our excellent volume on *Air Conservation*, for example, still has a lively sales record 6 years after publication. The history of the Herbicide Assessment Commission provides a dramatic demonstration of the impact that a well-organized and committed study group can have. Each spring, the

Association conducts a series of seminars for members of Congress and congressional staff officers on topics that we believe to be of special interest and importance to legislators. This year, the series includes discussions of human population control, solid waste handling, predation as a means of biological control, the total synthesis of food, engineering problems of the city, and technology assessment. One activity that could be extremely valuable in this connection would be a series of nontechnical but authoritative paperback monographs for the layman, particularly the government leader, on topics such as these.

One proposed program remains to be mentioned. At present, the conviction is growing within several of our major committees that, for the Association to be fully effective, it must complement its work at the national level with work at the local level. Accordingly, we are being urged to examine the feasibility of operating regional centers. Such an approach must include an assessment, in the light of such thinking, of the role of the Association's present divisions and of the relationship between the Association and the state academies of science. Certainly, regional centers would allow for a meaningful implementation of the concept of collegueship between scientists and teachers, government officials, and others concerned with society's problems at the local level. I might observe in closing that we are, by nature, an ecumenical organization and we recognize that a great deal more can be accomplished cooperatively than by working alone. Therefore, we seek your cooperation. Finally, all of us have heard the phrases "science and society" and "science for society" used with increasing frequency in the recent past. Involvement in concerns such as those that have prompted today's program has the happy faculty of bringing with it the helpful realization that science *is* society.