4 July 1980, Volume 209, Number 4452 SCIENCE

The Next 100 Years of *Science*

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At a centenary anniversary of *Science*, we should first celebrate the event itself. Not only has the journal survived 100 years, but it has been widely cited by the scientific community. In 1978, it was cited 59,057 times, giving it seventh rank among 3500 science journals in total citations, and second among general science journals. Perhaps more important, it got, over a 2-year period, an average of 5.9 citations per published paper. This high impact factor falls in the top 2 percent for the 3500 journals studied (*1*).

The journal *Science* is the flagship of the American Association for the Advancement of Science (AAAS), a society of about 128,000 members. In addition to publishing scientific reports and notices of scientific equipment, books, and conferences, it provides news and comments about current scientific affairs. Although its general policy is set by the Council and the editor is chosen by the Board of Directors, the Board and Council do not enter into operations. What we can be sure of is that the frequent careful sampling of subscribers' views keeps all concerned alert to the changing needs and agendas of the scientific community.

An immediate thrust should soon emerge from recent initiatives taken by its editor, Philip Abelson, that are resulting in a flow of important articles from the industrial and engineering community.

Let us discuss what things can be done, aside from avoiding nuclear war, to enlarge the probability that the next 100 years will continue to produce a *Science* as valuable as the one we now have. We require a vigorous scientific establishment, and that takes money for training and for basic applied research. Since the needed funds come almost entirely from outside science, we need good understanding by the decision-makers both of the value of science and of how science and technology operate. Even enlightened decision-makers cannot oppose their constituencies for long, and so the general public must also be able to appreciate science and its contributions, its limitations, and the dilemmas that new progress in science and technology pose for the modern citizen. Science is not a local enterprise, but is worldwide, and we need good communication among scientists and engineers, and, more generally, among scholars everywhere.

Carrying on the activities requires a steady influx of new brilliant well-trained people, and they will come if opportunities for rewards and advancement and an encouraging atmosphere for work continue, but not if these are shut off. Naturally, other fields need fine minds too: business and industry, government, art, the professions. And some of the minds devoted to these activities will also contribute to advances in science and technology. Finally, we could profitably use more information about conditions that lead to better research, more inventions, and to speedier but safe applications of science findings to human good.

These complicated and interconnected requirements for maintaining scientific progress seem to me necessary if we are to keep and even raise the standard of living throughout the world in spite of the dwindling supplies of some important natural resources. Consequently, I shall describe some activities of the AAAS that promote the huge program essential for an establishment that can produce science for *Science*.

Science for Decision-Makers

Appreciating those needs, both past and future, has led the AAAS to many of its activities in science, technology, and public policy. Since its establishment in 1973, the AAAS Committee on Science, Engineering, and Public Policy has taken the lead in this area. Our major effort has been directed at research and development, both the national R & D budget and policy issues. In addition to publishing a definitive report each year since 1976, AAAS provides a prompt review of the President's R & D budget and a report on congressional actions on that budget that are of special interest to policy-makers because of their timely character. The annual colloquium on R & D policy offers a unique occasion for the discussion of R & D-related issues by federal and industrial policy-makers and members of the scientific and engineering communities.

Seminars organized for the Congress also produce greater interaction between the scientific and engineering communities and the legislative branch of government. These treat such varied topics as protection of human subjects in research and risk-benefit analysis.

The AAAS also oversees fellowship programs like the one that permits scientists and engineers to work for a year as special legislative assistants in Congress. A dozen of our affiliates cooperate in this endeavor which now has grown to approximately 25 fellows annually.

In the future we expect to cultivate further these successful seminar and fellowship activities. Where appropriate, we would like to broaden the base of support within the scientific and engineering communities. New targeted fellowship and seminar activities aimed at public policy, with critical scientific and technological components such as those found in the fields of energy and environmental concerns, will be developed. The AAAS will assist the Executive Branch in developing a coherent and broadly

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0036-8015/80/0704-0021$00.75/0

based plan for scientific and technologic activities at the federal level.

A related but different area that has scarcely been touched is that of scientists themselves providing scientific leadership in citizen affairs. For developing such leaders we currently depend almost entirely on self-instruction and self-selection. Our Office of Scientific Freedom and Responsibility through its Subcommittee on Principles has been preparing, with the affiliates, codes of conduct that scientists may appropriately follow. Thus, over the next few years, we can expect heightened awareness of these issues on the part of scientists.

Public Understanding of Science

A proper base for the future of science requires understanding both by the public and by decision-makers.

Our latest venture, the magazine *Science 80*, will bring information about scientific progress to the general public. Among the contributions this journal may make are: improved knowledge about scientific events, improved scientific information for schools, better appreciation of how science develops and operates, and an appreciation of the scientific and technological issues that responsible citizens must deal with, including trade-offs. Its initial success in attracting subscribers suggests that it will be a mighty additional force in scientific education in the second century of *Science*.

The AAAS also administers a Mass Media Science Fellows Program for science and engineering students. The students who are awarded such fellowships spend a summer reporting news in science and technology for newspapers, magazines, and radio and television stations. The program is supported by the National Science Foundation and by grants from private and industrial foundations, as well as by the AAAS.

Communication Among Scientists: Regional and Annual Meetings

Let us turn now to the activities of the scientists themselves. They need to communicate. The future and form of our annual meetings forces extensive discussions among members of the AAAS Board of Directors. They view the rising costs of transportation and housing along with reduced funds available for such trips as posing long-run threats to the survival of the current form of annual meeting. This meeting focuses heavily on invited lectures, on state of the art, on policy, and on national problems, with rather less emphasis on contributed papers. By and large, scholars prefer to report their original research to the experts in the specialist societies.

At the same time, the complementary function of communicating reports on current research and discussing regional scientific and technological problems has been successfully developed by our three regional organizations: Alaska, Pacific, and Southwestern and Rocky Mountain divisions. Their meetings are often held at colleges and universities away from large cities. They aid many small societies by helping to organize the regional meetings and by creating a scientific event with sufficient breadth to attract substantial numbers of scholars.

Looking forward, by creating further regional divisions, the AAAS may be able to increase dissemination of current scientific research and at the same time strengthen relations with its affiliates whose members want to report their research to experts from their own fields.

The January 1980 annual meeting at San Francisco produced a Youth Program attended by thousands of enthusiastic young people. The Board plans such programs at future annual meetings. If held also at regional meetings, such youth programs would have a multiplicative effect.

The Board has been exploring, through its Office of Science Education, additional avenues for improved scientific education of young people, not only for entering science as a profession but also for citizenship.

International Science

In addition to organizing and joining in conferences on transnational scientific problems, for example, in Africa, India, Mexico, the Philippines, Australia, and New Zealand, the AAAS has been developing scientific relations in three international directions. By working with scientists from Central and South American countries and Canada and Mexico, the AAAS has been proud to aid in the development of a Western Hemisphere federation of associations for the advancement of science—the Interciencia Association—together with its trilingual journal, *Interciencia*. In Asia, the AAAS has exchanged visits and developed a program with the Scientific and Technical Association of the People's Republic of China. Members of that association plan to participate in the AAAS annual meeting at Toronto in 1981.

Through the Consortium of Affiliates for International Programs, we work with our disciplinary affiliates in the United States on international issues of concern to the scientific and engineering communities.

Although we already have cordial relations with the British Association for the Advancement of Science, perhaps we could go further and develop a mutually useful program. On a broader front, an effort oriented toward the European scientific organizations might produce valuable results. Generally speaking, successful plans depend on a coincidence of interests and of interrelations among individuals, and so their partly accidental timing has to be accepted. Possibly opportunities in other parts of the world will suddenly emerge, and our Office of International Science and the Board of Directors stand ready to respond. At our *Science* centennial, it is humbling to realize that Portugal is celebrating its 200th scientific anniversary.

Over the next few decades, we should look forward to more contributions to science and *Science* from the Third World. What efforts would lead to this end?

Opportunities in Science

For science in the next 100 years to prosper here, we must be able to continue to introduce young scientists into the system. The shrinking college population in the United States caused largely by the reduction in the birthrate has put heavy pressure on colleges and universities to reduce their staffs. This constriction has almost entirely closed out scientific job opportunities in some fields of academia. Worse is coming.

As we look forward to the effects of the changing laws governing retirement of professors, the consequence for the academic employment of young people may be expected to be more drastic than anything we have yet seen. Therefore, if we are to maintain an orderly entrance into the sciences by youth, it is urgent that the academic institutions, the professional scientific societies, the foundations, industry, and government organize themselves for this coming crunch.

Without in the least deprecating the accomplishments of older scholars, we do know that the young ones have the most systematic education in the latest knowledge of science across a broad range of topics, and that they are not as hampered by administrative and fiscal responsibilities as older scholars.

That the government does consider

young research investigators is shown by recent data (FY 1978) from the National Institutes of Health where 1446 new principal investigators received awards, a rise from 855 of 10 years earlier. As a percentage of all principal investigators of NIH R01 grants, new investigators have averaged about 13 percent over the 5 years from 1974 to 1978. In competing for new grants as opposed to renewals, new investigators were awarded more than 50 percent of the grants in FY 1978.

This bind on jobs in science comes at a doubly bad time because the relationship between the government and the scientific establishment in the research universities has been worsening. What began decades ago as an exuberant symbiosis has become grimmer as the government presses for more paperwork and tighter accounting. We must strive for a new understanding in these matters. Congress, of course, deserves a good accounting, but we must have elbowroom in the system if we are to get good productivity out of our research.

Rensis Likert (*2*) found in business research that one can for short periods tighten up an organization and seem to gain from it, but he found that in a very few years this tightness leads the better people in the organization to leave it. It takes a while because highly placed people cannot change posts instantly. We are beginning to see what may be a similar effect in the medical community. The recruiting of clinical scholars for biomedical research is becoming more difficult. The pay is better in practice, and the anxieties about funding scarcely arise.

Perhaps the new problems related to retirement and tenure could be made an opportunity for repairing the erosion that has already taken place in goodwill between the research universities and government.

Through its Office of Opportunities in Science, the AAAS has produced and plans to continue a vigorous program of support for the participation of women, of minorities, and of handicapped in science. The impending extra problem of jobs will make these efforts more difficult.

Returning now to the long-run problem, through unemployment we can create a gap in our scientific age-continuum just as surely as the Chinese did with their cultural revolution. They are now valiantly trying to redress this loss, and we can and should profit from their bitter experience.

When employment becomes more difficult, it is useful to monitor closely what is happening. Such organizations as the Scientific Manpower Commission, the Engineering Manpower Commission, and the Commission on Human Resources of the National Academy of Sciences–National Research Council may well need additional support if we are to follow employment in the scientific community with sufficient care.

Research on Research and Development

In the past, we have had many discussions of the comparative values of basic and applied research and of whether technology drives science or vice versa. While finding these stimulating to the heart, I have not found such discussions profitable, though understanding such issues might have valuable policy implications. Two studies oriented toward innovation, Project Hindsight by the Department of Defense and the Comroe-Dripps (*3*, *4*) study, although opposed in their conclusions, agree on an important factual finding. Major technological innovations, military or medical, require many distinct inventions (findings or innovations) for their success. Since these component inventions or research findings came from a variety of fields of unrelated research, we clearly need a far-flung productive research establishment if we are to advance complex technology.

So far our studies of the historical situation in past research has not done a great deal to tell us how to organize or reorganize our programs. As a matter of fact, we seem in many sciences to be moving to larger and larger teams. Apparently, effectiveness improves as sizes grow up to three to five or five to seven, but effective sizes depend on the skill of the research leader and on the discipline, according to Stankiwicz (*5*). Blume (*6*) says that we should not expect universal principles of scientific management, but that the comparative analysis of scientific communities might do much to help us understand the workings of science. In such studies, he says, we might find how organizational factors, resources, and division of labor vary in their effects from one specialty to another.

Although we can scarcely instruct anyone how to do this research on scientific productivity and scientific management, we should encourage a good deal more of it and not expect much payoff soon.

The Goals

The major problems facing the world require extensive scientific research and the development of much technology. Such problems as defense, energy, cleaning up the environment, and dealing with the information explosion—as well as new attacks upon illnesses and the opportunities to take advantage of the recent marvels in biology—will require extensive research from the most basic to the most developmental. Thus society has much for scientists, technologists, and engineers to do. The AAAS will build on successful previous efforts and cooperate with its affiliates to expand their joint contributions. By increasing the public understanding of science and the responsibility of scientists to communicate with the public and decision-makers, and by helping scientists talk to one another, we hope to bring science and its methods to the public so that we enhance the value of both scientists and nonscientists as citizens. It will take a whole society and a whole world to produce another 100 years of *Science*.

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