DIRECTOR'S STATEMENT

Albert Einstein once observed: "To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks real advances in science." This 18th Annual Report of the National Science Foundation (NSF) is the story of men who have advanced science, during the past fiscal year, by hard work and "creative imagination." The highlights of this story are in the introductory chapter of this Report, and are followed by detailed accounts of some of the activities supported for creating and validating scientific knowledge; transferring and using this knowledge; and maintaining and improving the means for accomplishing these ends.

I realize that the proposition that science serves man while simultaneously pursuing knowledge for its own sake is not new. But in these times when so many judgments must be tentative and uncertain; and when "ignorance is bold, and knowledge reserved" it is important not to lose sight of and to observe again the economic and social content with which science is invested. By so doing, we testify in a concrete manner to the humanity of science.

Testimony to this effect is found throughout the Report, and so I will select but one example to illustrate the point. For many years NSF has supported the research by George Wald of Harvard University in the chemistry of visual pigments and the molecular changes associated with the absorption of light by these pigments.[1] From these studies have come inproved understanding of the way in which light is converted to a nerve impulse in the retinal rods and cones of the eye, and the causes of color blindness.

The scientific value of Dr. Wald's work merited recognition by his sharing in the award of the Nobel Prize in Medicine or Physiology in late 1967. In his address on receiving the Nobel Prize, Dr. Wald remarked that experimentation was "like a quiet conversation with Nature. One asks a question and gets an answer; then one asks the next question and gets the next answer. An experiment is a device to make Nature speak intelligibly. After that one has only to listen.[2]

[1] *National Science Foundation 18th Annual Report for the Fiscal Year ended June 30, 1968* (hereinafter referred to as Report), pp. 83–84.

[2] George Wald, "Molecular Basis of Visual Excitation," *Science,* vol. 162, No. 3850, October 11, 1968, pp. 230–239.

There are many ways of having "conversations with nature." Sometimes questions deal with the atomic or molecular states, at other times with broad, environmental systems. Thus, at the molecular state in biology, interrogations have established the general features of chemical reactions which yield the energy and chemical structures required by living organisms. Now our questions are directed to the regulatory processes which confer upon biological systems their unique characteristics of organization, replication, and self-correction.[3] A major achievement in the past year has been the successful replication, outside of the living cell, of a viral DNA molecule with biological activity. In the words of President Johnson:

> These men have unlocked a fundamental secret of life. It is an awesome accomplishment. It opens a wide door to new discoveries in fighting disease and building much healthier lives for all human beings.[4]

Increasingly, we have come to recognize the interdependence of the components of the natural systems about us, and the problems which man is creating as he modifies his environment. Our questions in these areas are as broad as the oceans [5] and the atmosphere [6] and the total biological community.[7]

In contrasting molecular and microscopic methods to environmental and macroscopic approaches to scientific research, one should keep in mind that the comparison represents a perspective and a mode of investigation rather than some hard and fast constraint on a scientist. Also, environmental studies are grounded in the basic knowledge and understanding that we have of the atomic or molecular states. Perhaps the best illustration of this point is to be found in research in astronomy which is concerned with the greatest system of them all—the universe. But in studying the environment of space, nuclear and molecular interactions as revealed by spectral phenomena provide indispensable clues to the astronomer.

Whether we ask questions of nature at the smallest or the largest levels, recurring patterns in problem solving may also be noted regardless of the scientific discipline involved. Two recurring tactics of investigation include mathematical model-building and testing; and tracing of the pathways taken by natural processes in order to see how they operate.

Mathematical models have been used in extraordinarily diverse problems. For example, in the case of a ground fire burning through compacted leaves and debris or a brush fire, models have been derived

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[3] Report, pp. 84–85.

[4] *Weekly Compilation of Presidential Documents*, vol. 3, No. 50, December 18, 1967, p. 1714.

[5] Report, pp. 116–126.

[6] Report, pp. 92–116.

[7] Report, pp. 82–83.

which relate wind velocity and fuel moisture content in a way which makes possible more accurate predictions concerning the effect of these variables on fire spread.[8] This particular example of model-building is of special importance because only a small fraction of the substantial sums spent on fire research in the United States each year is devoted to fundamental studies of this type. And yet, it is such an approach which experience tells us will have the best chance of success in reducing the large annual fire losses experienced in this country and around the world.

The tracing of pathways as another way of answering questions has both large- and small-scale dimensions. At the atomic level, techniques have been perfected which permit the isolation of ions and electrons for comparatively long times.[9] With this new capability, subtle differences in electronic energies can be measured to phenomenal accuracy—even as high as one part in a billion. As a result, the road is opened to improvements in atomic theory, as well as laser technology.

Tracing of pathways is not limited only to the making of more precise or refined measurements. Pathways may also be traced, on a broader scale, through studies of chemical interactions between marine organisms, and the dynamics of the marine food chain.

Whatever the value may be of the answers we receive to our questions, there is another more subtle benefit which is relevant to this discussion. We live in a time when tradition and knowledge are subject to attack, from those who, in challenging conventional and transmitted wisdom, prefer to rely on subjective reactions and stress visual and personal rather than intellectual images. This attack has contributed much toward the disequilibrium and anxiety we see in our society. As a counterbalance, the methodology of science is relevant because it builds towards orderly sequences, coherent theories, and values. It has demonstrated how to question tradition and yet draw on past insights; it relies on intuition while demanding objective verification and testing. The very thought processes and procedures of science, in effect, become a model on which society can draw to help chart its future course.

The patterns of NSF activities in support of research and education in the sciences described in this Annual Report do not take place in isolation. They are profoundly affected by the ambient legislative and financial environments—both of which were marked by important developments in fiscal year 1968.

NSF Legislative Environment

To turn to a seemingly different, but nevertheless closely related subject, a major legislative revision of the NSF organic statute was

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[8] Report, pp. 137–139.

[9] Report, pp. 48–49.

passed by Congress and signed into law on July 18, 1968. Congressman Emilio Q. Daddario of Connecticut introduced the original bill in the House of Representatives in 1966. In the Senate, the Special Subcommittee on Science under the chairmanship of Senator Edward M. Kennedy, added to the long work carried out by the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics, and introduced several important amendments incorporated into the final act. A full evaluation of the significance of the new legislation can come only with the passage of time. However, it is evident that this new act represents one of the most significant legislative changes in the functions and organization of the National Science Foundation.

It is important to realize that the revised act not only makes changes in the NSF charter and operations, but that it represents a clear congressional endorsement of the importance of the central functions of the Foundation, namely, the advancement of science and science education. In the words of Senator Harris, "No past investment America has made in any field has brought returns which exceed those it has received from its investment in scientific research. American affluence and our standard of living are in large measure attestations of this fact." The new legislation encompasses not only important changes in the charter and operations of NSF but it represents a clear congressional reaffirmation of the role of the NSF in the promotion of national science. I believe that the NSF can take much satisfaction in knowing that during the debate on its legislation, Senator Edward Kennedy expressed a sense of the Congress by stating that "The National Science Foundation is charged with supporting the development of American scientific expertise. This is a very broad charge. It is also a very great challenge. The record of the National Science Foundation in carrying out the charge and meeting the challenge is a proud one."

As for changes in NSF activities, the Congress assigned new areas of responsibility to the Foundation and explicitly emphasized the importance of some of the previously authorized endeavors.

One important extension of NSF responsibility is the authorization to initiate and support applied research activities in academic and other nonprofit institutions. This new authority undoubtedly will affect a number of programs of the Foundation. It will also make it possible for the Foundation to support efforts at academic institutions aimed at providing the knowledge base required to deal with the contemporary problems of our modern science-oriented society. However, it is not the intent of the Foundation to support applied research at the expense of the important fundamental science activities which it now supports.

The new act specifically emphasizes the importance of social science research, which is mentioned explicitly in the new law as one of the areas in which the research potential of the Nation should be strengthened. In view of these recently authorized NSF responsibilities, it is the intent of the Foundation to provide active leadership in the development and support of research programs pertinent to contemporary societal problems. Only through such research efforts can we expect to provide the necessary knowledge and methodology required for the solutions of these problems.

In this connection, the NSF has steadily increased its support of social science research and related activities as part of its effort to assist in advancing the body of scientific knowledge and techniques which are fundamental to any later use of them in real world problem solving. The social sciences are growing, yet they remain comparatively underdeveloped and their body of expertise is comparatively limited. Although the research techniques may not be as precise as in the natural sciences and the methods not as easy to control as in laboratory settings, the potential contribution to problem solving is nevertheless more than enough to justify the risk. We foresee a demand for resources to use on these problems which will be on a substantially larger scale than has been typical for social science research grants in the past. Meaningful research, be it basic or applied, that is related to environmental and population problems for instance, requires multidisciplinary groups of social scientists and others working in collaboration through augmented or new academic research centers or institutes.

There are enough examples of positive contributions from the techniques that have been developed and the knowledge which has already been acquired to warrant continued and increased support of further efforts to advance the social sciences. It is recognized that money alone will not assure major advances or instant solutions in this area or any other. But with increased resources, social science research can be strengthened in quality and increased in rate of productivity by providing stable, broad-gauged support for highly qualified investigators. The results will not only add to our general fund of knowledge about human beings and their institutions, but often may provide information which will assist in the resolution of pressing problems of society. In some cases, the information to resolve at least part of the problems is available, or essentially so, but economic, social, and political hurdles prevent appropriate action. In other cases, where many "social" factors are involved, e.g., racial issues, the solution depends not so much on science as in the attitudes of people. In such circumstances, it is important to realize that science may help but should not be expected to be decisive in the policy decisions that must be made.

It seems only proper that the Foundation, which has developed such

close relationships with the academic community, was authorized to help provide the means to stimulate our universities to put their intellectual resources to the task of augmenting knowledge that will assist in the solution of some of these most important problems of our times. In selecting programs for development, the Foundation will concentrate on research areas which are not of focal interest to other agencies and which deal primarily with the interaction of man and the physical world and man with man himself.

In the course of the next year, NSF will give thorough consideration to the development of these new programs. This will include: formulation of criteria for support; determination, with the aid of various advisory groups, of the areas of research on which we will concentrate; and establishment of the most effective mechanisms by which creative energies can be brought to bear on the successful implementation of this new congressional mandate.

Another important mandate assigned to the NSF by the new legislation is to initiate and support scientific activities relating to international cooperation and in furtherance of national objectives abroad. Now, NSF may support scientific activities in pursuit of objectives of greater scope than the promotion of science and science education per se, provided such activities coincide with national policies. This new mandate will considerably enhance the Foundation's role in regard to science in the international area. At the present time, we are assessing the implications to international science activities of the new legislation in order to determine how best to pursue the goals of stimulating science not only at home but abroad, of encouraging increased cooperation between American and foreign scientists, and, finally, of supporting American and foreign scientists in advancement of U.S. national interests and objectives abroad.

The new act also assigns a major new responsibility to the National Science Board. The Board is required to provide Congress with an annual report on the status and health of science and its various disciplines. This report, which is not intended to be comprehensive every time, will provide an excellent opportunity to provide the Congress with information on specific timely and significant developments and to identify noteworthy achievements and problem areas for consideration by the Congress in its deliberations on policy matters related to science and technology. Another pathway of communication has been opened up by the establishment of a new requirement for annual congressional authorizations for appropriations. Because of the growth of the NSF programs, it was felt by the Congress that the permanent authorization of the original NSF Act of 1950 should be replaced by annual authorization reviews. Arrangements are currently underway to prepare for such hearings, and it is hoped that the ensuing dialogue

will not only provide a better information channel but will develop a better understanding of common problems.

The act redefines the activities of the Foundation's director and the National Science Board. It reaffirms the responsibility of the NSB to establish the overall policies of the Foundation, while at the same time relieving it of some of its responsibilities for the operation of the Foundation. In addition, the act includes language intended to assure that the Board will have a strong advisory voice in national science policies as promulgated by the administration.

Earlier in this statement, we noted the linkage in scientific research between molecular and microscopic methods, and broader microscopic approaches to environmental systems. In a similar way, the new mandates from Congress may be viewed as being aimed at how the individual fruits of science, and the wisdom of scientists can be integrated into the system of government and society including international systems.

NSF Financial Environment

Dollars are another form of legislative guidance, and there has been much concern that the current budget stringencies will hamper, if not harm, the Nation's science effort. Looking back over the 5-year span, fiscal years 1964–1968, we find that funds available to the Foundation have increased. Unfortunately, the increase has not kept pace with the ever growing demand for support of high quality projects in scientific research and education. As a result of the cuts made from recent NSF budget requests, the Foundation has been compelled to limit its support for new projects and to reduce the funds for its programs, especially graduate facilities, specialized equipment (e.g., chemistry research instruments), fellowships and traineeships.

It is not possible, as of the writing of this statement, to assess fully the impact of fiscal year 1969 budget cuts on the various programs of the Foundation. It seems clear, however, that the limited funds that will be made available will again require reductions in support for new investigators, for facilities, for specialized equipment, for development of additional strong academic science centers, and for science education projects, including traineeships. It is our intention to use the funds that are made available for preserving the continuity of the scientific enterprise to the fullest extent possible. It is primarily for this reason that we feel it desirable to limit our available funds for hardware-oriented porgrams so as to maintain as much as we can of those programs where continuity of the scientific careers of people is involved.

The National Science Foundation has the primary responsibility for assuring that the scientific base of the Nation is maintained and strengthened through the totality of Federal programs involving sci-

ence, particularly at academic institutions. Other Federal agencies are also concerned with this goal, but they are more directly concerned with specific and immediate mission-related objectives involving the ultimate use of science and technology. In pursuing their goals, the mission-oriented agencies quite properly support basic as well as applied research in relevant areas. Thus, various aspects of the mission-related scientific porgrams of the Federal Government contribute to the long-range goal of strengthening science in the United States, but this is not their main purpose, and the expansion and contraction of such programs must be determined on the basis of immediate mission requirements. Government-wide, therefore, the Foundation's role as a major source of support for all scientific research and science education is of critical importance in developing and sustaining a superior U.S. capability in science.

In fulfilling this responsibility, the National Science Foundation seeks to determine national needs for particular kinds of scientific research by assessing both internal considerations (those generated on intellectual grounds) and external considerations (those suggested by problems of society such as air and water pollution, overpopulation, etc.). The Foundation is committed to administer its overall support of scientific research programs in such a way as to avoid, insofar as possible, sharp fluctuations in the total national level of activity in each broad area of science.

As long as we were in a period when Federal support for R&D was rising, it was possible for the NSF to carry out this commitment to balanced opportunities for progress in all fields of science. We, and other principal Federal agencies supporting research, now find ourselves in a period when expenditures must be limited, and our obligational authority to budget for research and education in the sciences has been reduced. At the same time, faced with rising costs, an apparent decrease of public support and interest, and increased needs, the NSF finds itself at the point of converging pressures which seriously impair its aim of supporting the stability and progress of the scientific and academic communities.

Conclusion

In this statement, I have tried to synthesize some general ideas and conclusions from a review of the past year's activities by the NSF and changes in its environment. It has been said that every country gets the science it deserves. In the light of the intellectual and social ferment around us, certainly we cannot afford to be without the very best science.

I believe that this report presents a record of noteworthy accomplishment. Under the new charter established by Congress, we look forward to the new challenges and opportunities of the future.