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NATIONAL SCIENCE FOUNDATION PEER REVIEW

VOLUME I

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A REPORT

OF THE

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

NINETY-FOURTH CONGRESS

SECOND SESSION

Serial V

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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, D.C., January 19, 1976.

Hon. OLIN E. TEAGUE,
Chairman, Committee on Science and Technology, U.S. House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: During the summer of 1975 the Subcommittee on Science, Research and Technology held six days of oversight hearings into National Science Foundation peer review procedures. These hearings were part of the Subcommittee's continuing oversight of the Foundation.

The following report of the Subcommittee is based upon the analysis of the record which has taken place since the hearings. The report contains conclusions and recommendations of the Subcommittee. It is submitted for the use of the Committee on Science and Technology.

Sincerely,

JAMES W. SYMINGTON,
Chairman, Subcommittee on Science, Research and Technology.

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I. Summary

A. Introduction

The Subcommittee on Science, Research and Technology of the House Committee on Science and Technology held six days of hearings during July 1975 as part of the Subcommittee's continuing oversight of the National Science Foundation. This report stems from those hearings and is based upon the oral and written testimony submitted during the hearings. The question on which the Subcommittee's investigation has been focused is: "Once monies have been appropriated to the Foundation and the division of those monies among disciplines and purposes has been agreed upon, how does the Foundation go about making individual awards?" This topic was appropriate for several reasons. Foremost among these were: Congressional and public concern that the Foundation might be supporting questionable research, spreading belief that government operations ought to be open to public scrutiny, and concern that tightness of funds might result in complaints about the Foundation's decision-making systems from the scientific community.

The mode in which the Foundation provides most of its support for scientific activity is to fund projects directed by individuals at institutions. The Subcommittee believes this is a sound mode of support and has turned its attention primarily to the question of how projects are selected for funding. The Foundation's selection procedures are based principally upon evaluations of project proposals which have been submitted to the Foundation. Evaluation procedures usually include an assessment of the merit of the proposal and the competence of the proposer by experts from outside the Foundation in the subject matter of the proposal. The experts are considered peers of the proposer. Because of their review, the Foundation's evaluation system is commonly called a peer review system, and the hearings have been designated "Peer Review Hearings."

In fact, the Foundation employs a rather wide variety of evaluation procedures tailored to fit differing types of programs, so that caution is necessary in deriving or applying general rules. The procedures normally include reliance on staff judgement plus evaluation by individual peer reviewers, evaluation by an assembled panel of peer reviewers, or both. Other elements that may be included are: site visits, National Science Board action, or consultation with other funding agencies.

Witnesses who appeared included two Congressmen who asked to testify, four principal Foundation witnesses, ten scientific experts from outside the Foundation who were selected by the Subcommittee for their special competence and viewpoints, and seven other minority witnesses. The two Congressmen, Rep. John Conlan of Arizona and Rep. Robert Bauman of Maryland both had criticized the Foundation in matters other than proposal evaluation before the hearings and were both critical in their testimony at the hearings. Foundation witnesses

devoted much of their testimony to describing how the Foundation makes decisions and what the resulting distribution of Foundation funds and reviewers has been; they found fundamental soundness in existing Foundation procedures. The experts selected by the Subcommittee from outside the Foundation were generally supportive of the Foundation while making suggestions for improvements. The seven other minority witnesses, all of whom had been suggested by Rep. Conlan, were critical of the Foundation. Philip Handler, President of the National Academy of Sciences, submitted important written testimony although he had been unable to appear in person because of illness.

B. ISSUES

A wealth of interacting issues concerning peer review was considered by the Subcommittee. The amount and type of information available for helping reach judgments varied widely from issue to issue. Consequently, there is variation in the type of findings and recommendations the Subcommittee has formulated. The issues are presented in chapter IV and analyzed in chapter V. Chapter VI contains the Subcommittee's recommendations organized by issue. This summary is directed only to selected key points.

C. PRINCIPAL FINDINGS AND RECOMMENDATIONS

In the Subcommittee's judgement, the most important single consideration of the Foundation's peer review system is whether the Foundation's awards lead to the advance of science in the most effective possible way. The Subcommittee's principal findings and recommendations are:

1. Finding: Procedures relying on peer review for evaluating applications for scientific research awards can lead to the effective advance of scientific knowledge. The National Science Foundation's peer review evaluation systems appear basically sound.

No method superior to peer review has been found for judging the scientific competence of proposers. Scientific peers are better able than others to judge the design of proposed work, the importance of proposed work to the scientific field, and the past performance of the proposer. Appropriate peer review procedures generally lead to the support of proposals in a high quality range. Using peer review procedures the Foundation has successfully fostered significant advances in basic science over the past 25 years.

Recommendation: The National Science Foundation should continue to use some form of peer review. Congress should not require major changes at this time in the methods used by the Foundation for proposal evaluation.

2. Finding: Certain problems exist with the Foundation's peer review evaluation processes and related operations. Substantial changes in the operation of the Foundation's peer review systems have been proposed which possibly could lead to improvements in the system's effectiveness for consistently selecting the best proposals, and in the acceptability of the systems to potential applicants, the scientific community, and Congress.

Recommendation: Some corrective actions should be taken immediately and certain proposals for substantial changes should be thoroughly investigated and instituted if judged worthy.

D. IMMEDIATE ACTION

The recommendations for immediate action mentioned in the second principal recommendation, together with brief discussions of the rationale for each, follow.

Recommendation: The Foundation should prepare an organized compendium of its policies in writing and assure that it be widely available.

Examples of staff actions contrary to Foundation policy were given at the hearings. Although the Subcommittee does not believe such actions are widespread, the compendium of policy and procedure memoranda submitted by the Foundation, because of its size and lack of organization, gives the Subcommittee little reassurance that the staff can stay abreast of current policies even with the best intentions. The Subcommittee believes that the scientific community should be able to understand and stay current with Foundation policies. At present there is no way such understanding can be easily acquired.

Recommendation: The Foundation should devise systematic methods of ensuring that competent reviewers are identified and used regardless of institutional affiliation or geographical location. No reviewer should be overused in relation to his or her abilities.

The Subcommittee believes that reviewing should be widely distributed among competent potential reviewers. On a Foundation-wide geographic basis, rather broad distribution appears to have occurred. There are, however, no systematic methods employed by the Foundation for assuring wide distribution or determining whether any given reviewer has been too frequently used.

Recommendation: The National Science Foundation should perform random audits of the decision processes used for individual grants. The Foundation should report to Congress describing the system it uses for this type of audit.

Recommendation: The Subcommittee on Science, Research and Technology of the House Committee on Science and Technology and the Subcommittee on the National Science Foundation of the Senate Committee on Labor and Public Welfare should work with the Foundation to establish procedures whereby the Subcommittees can have effective access to certain confidential information of the Foundation. The procedures should be designed to maintain the highest degree of confidentiality of the information that will allow effective Congressional oversight.

These two recommendations address the widely-discussed issue of bias in peer review systems and incorporate the Subcommittee's belief that oversight of the Foundation's peer review system should be based on an attitude of trust combined with vigilance over the system to assure that trust is warranted.

It is noteworthy that although the severest critics of Foundation peer review have labeled it "an incestuous buddy system" no example of bias on the part of reviewers was mentioned at the hearings. Conversely, neither was it demonstrated that the system is not biased. The reasons for this lack of surety appear to be principally (i) talent is concentrated, so that the appearance of buddy systems cannot be avoided, but (ii) judgements of whether a reviewer has been biased in a particular instance are almost wholly subjective.

The recommended audits should provide a check of the relations among the Foundation staff, proposers, and reviewers in many individual

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instances, and the combined results of many audits should help give statistical evidence for or against bias.

Arranging for access to Foundation information by the two Congressional committees charged with authorization of the Foundation's budget is necessary to proper Congressional oversight.

Recommendation: The Foundation should include in each letter announcing a funding decision to an applicant either a statement of the methods and rationale of the decision or a statement that such information will be provided on request.

Applicants for Foundation awards have the right to know the methods and rationales of decisions made concerning their applications. It is not clear that applicants have had adequate access to such information in the past.

Recommendation: The Foundation should fill reasonable requests for data concerning the distribution of funds by the Metallurgy and Materials Section within the constraints of the Foundation's policies concerning the confidentiality of such information.

The Subcommittee found that evidence presented which purported to show that the Metallurgy and Materials Section has distributed funds inequitably is highly questionable. The primary reasons that the evidence is questionable are: (1) citation analysis alone was used to produce a measure of scientific ability, but citation analysis standing alone appears to be inadequate for that purpose, and (2) to be meaningful, an analysis of funding patterns must encompass all agencies providing support. Additionally, many issues concerning technical aspects of the evidence have been raised. It was not clear, however, whether the Foundation had adequately filled requests by the principal witness for information. This recommendation addresses that point.

E. NATIONAL SCIENCE BOARD

In the course of considering peer review at the Foundation it became clear that there are many important issues which should not be judged without further careful study by persons familiar with peer review systems, further collection of information, or further analysis after the elapse of a period of time. The Subcommittee considered arguments that Congress ought to judge these issues and set Foundation policies but is convinced it is preferable to keep the responsibility for setting Foundation policies lodged in the National Science Board as legislated in the Foundation's organic act.

The Subcommittee recommends in this report that the National Science Board devote further study to eight issues. It is desirable that the Board turn its attention promptly to these issues. The Subcommittee will stay informed of the Board's progress to assure that the issues are sufficiently addressed:

Finding: There is a clear need for firm policy guidance in the management of peer review at the National Science Foundation. Experience in science and with the scientific community, as well as carefully assembled objective information, are essential to the formation of sound policies governing peer review.

Recommendation: The National Science Board should have primary responsibility for the establishment of policies governing peer review at the National Science Foundation.

The National Science Board should—

1. Study the support of innovative research and report to Congress.
2. Study the support of young scientists and report to Congress.
3. Study the funding of research at undergraduate-teaching institutions without graduate departments (colleges) by the Foundation and report to Congress.

4. Study the extent to which the Foundation should rely on peer panel review and report to Congress.

5. Establish an internal Foundation program to monitor problems arising from the mismatch between the size of the scientific community and the amount of Foundation funds available for support of that community, and should report periodically to Congress.

6. Study the question of whether the National Science Foundation should have formal procedures for considering appeals of decisions made on award applications and should report to Congress.

7. Study the effects of publication of the list of reviewers used by the Foundation and consider whether publication of the list in a less aggregated form might be desirable.

8. Collect further information concerning effects on the peer review system of the level of confidentiality in which peer reviewers' names and verbatim comments are held. The Board should report the information and any conclusions that may be drawn from it to Congress. Further changes in the level of confidentiality of the Foundation's peer review system should be made slowly if at all.

F. OPENNESS

The last two recommendations for Board actions are part of an inclination by the Subcommittee towards openness.

Recommendation: The greatest degree of openness of the Foundation's award decision-making process consonant with effective proposal evaluation and reasonable efficiency should be achieved.

The most thoroughly discussed issue of the hearings was the question of the extent to which openness of the decision-making process can coexist with the effective evaluation of award applications by the Foundation. Arguments are presented in some detail in chapter V of this report. The Subcommittee has concluded that since (i) the issue appears to be critical, (ii) the Foundation has recently increased its degree of openness and, (iii) in contrast to the number of arguments, hard facts about the situation are few, the best course of action at this time is to evaluate the effects of the recent changes and continue study of the issue by the National Science Board as indicated above.

Other parts of the thrust towards openness already mentioned are the recommendations that the Foundation should prepare and distribute an organized compendium of its policies and should include information about the methods and rationale of its decisions when the decisions are announced to applicants.

G. CONGRESS

From its study of peer review at the Foundation, it has become clear to the Subcommittee that the role of Congress also requires attention.

Recommendation: Congress should not require Congressional review of individual research awards.

The Subcommittee believes that Congressional review of National Science Foundation awards would introduce serious problems into the government's support of science, including: (i) politicization of the award decision-making process, turning it away from support of proposals on their merit, (ii) less willingness in the Foundation to support innovative ideas, and (iii) lengthening of the time it takes applicants to obtain funding and proceed with their research.

Recommendation: If Congress undertakes studies of the geographical distribution of funds for scientific research by any Federal agency or agencies, such studies should explicitly put support by one agency in the context of total Federal support.

There is division of opinion among members of the Subcommittee concerning the desirability of requiring that the geographical distribution of National Science Foundation funds meet some standard of evenness. Some argue that the Foundation should support the best research wherever and in whatever concentration it may be found. Others believe some degree of evenness should be required. The Subcommittee finds that rational consideration of the geographical distribution of Federal funds for scientific research requires that funding patterns be considered on a government-wide basis, including all agencies providing significant amounts of money for scientific research, not only the Foundation.

The Subcommittee is, nonetheless, mindful of the requirements of Public Law 81–507, Section 3(e), the Organic Act of the Foundation, and cautions the Foundation that it has a special statutory duty to avoid undue concentration in its grant decisions.

Recommendation: Congress should not propose or acquiesce to reductions in the overlap of fields of basic scientific research supported by various Federal agencies without further investigating the advantages and disadvantages of such overlaps.

It has been argued that the existence of multiple funding sources in the Federal government has been one of the great strengths of American science—that the best way to prevent over-direction of basic research and stifling of innovation by the Federal bureacracy is to ensure that there is more than one source of support. These arguments deserve careful consideration. This recommendation does not mean the Subcommittee favors duplicative research projects.

II. Background

A. LEGISLATIVE MANDATE

During the fall and winter of 1974, the House of Representatives Committee on Science and Astronautics was reorganized. Its name became the Committee on Science and Technology, its responsibilities for legislation and oversight were enlarged, and the number of its subcommittees was increased. The former Subcommittee on Science, Research and Development was renamed to be the Subcommittee on Science, Research and Technology. James Symington, Democrat of Missouri, became the Subcommittee's chairman—he had not been chairman earlier—and the size of the Subcommittee staff doubled.

These changes permitted the Subcommittee to begin exercising fuller oversight of the National Science Foundation than had been possible in former years, although the Subcommittee's charge regarding the National Science Foundation was not new.

Discussions within the Committee on Science and Technology and between the Subcommittee and the Foundation during the spring of 1975 resulted in the selection of "peer review" as the topic for the July oversight hearings (authorization hearings on the Foundation's proposed budget for Fiscal Year 1976 and oversight hearings on the Foundation's education programs had been held by the Subcommittee in early 1975 under Mr. Symington's chairmanship).

B. SURROUNDING EVENTS

Four factors made the selection of peer review at the Foundation particularly appropriate as the topic for oversight hearings: congressional activity, budget concerns of the public, the desire for freedom of information, and increased competition for Foundation grants.

1. Congress

Several Congressmen had expressed concern that the Foundation seemed to be supporting useless research. The most widely reported allegations of waste were voiced by Senator William Proxmire and Representative Robert Bauman. Representative John Conlan had called attention to what he said were abuses of peer review by the Foundation. Many other Congressmen, while not so outspoken, had received letters from their constituents questioning expenditures on individual scientific grants. These Congressmen wanted to know whether the Foundation was performing competently.

2. Public

The letters from constituents almost invariably had resulted from attention being drawn in the press to titles of scientific grants that sounded silly. The public was generally concerned with the size of the Federal budget and the size of the deficit in that budget. This concern was fed by columnists who trumpeted examples of purported Federal waste. While it is naive to judge a scientific grant by its title, the

public's concern was not to be dismissed without an investigation designed to assure that money was being spent for worthwhile purposes.

3. Freedom of Information

A widespread belief that government operations ought to be open to public scrutiny to the greatest extent feasible had developed during the early 1970's. National events showed this belief to be well founded, and reinforced it. The Freedom of Information Act and the Federal Advisory Committee Act sprang in large part from a desire for openness in government. In the spirit of openness the National Science Board had voted at its meeting of June 20, 1975 to make changes in the Foundation's peer review system which would provide fuller information to grant applicants and to the public. It was appropriate for the Subcommittee to examine the Foundation's peer review application evaluation procedures to determine the extent to which freedom of information can coexist with the effective evaluation of applications for scientific grants.

4. Competition for Foundation Funds

The size of the scientific community had grown rapidly for the last decade. Foundation funds for basic research, expressed in constant dollars, had increased only enough during that time to support continuing Foundation programs and projects transferred to the Foundation from other agencies at a roughly constant level. As a result Foundation staff members anticipated an increase in complaints from disappointed applicants. The Foundation wanted Congress to understand its prcedures.

Related events, all of which tend to exacerbate the difficulty of properly distributing funds for scientific research, included the budget difficulties of colleges and universities and the halt in the growth of the nation's scientific faculty at four-year colleges and universities.

C. HEARINGS

1. Focus

The central question on which the hearings focused, and on which this report focuses is, "Once monies have been appropriated to the Foundation and the division of those monies among disciplines and purposes has been agreed upon, how does the Foundation go about making individual awards?" Investigation of the central question required first that the Subcommittee obtain an improved understanding of how the National Science Foundation decides which scientists and projects will receive Foundation funds. Second, it was necessary to compare operations at the Foundation with other methods for allocating Federal money to scientific research projects in the private sector. Investigation was aimed towards determining whether the Foundation is doing a good job in this area of grant allocation. Are its decision-making processes theoretically sound and practically effective?

The intended focus was maintained well throughout the course of the hearings. There were only brief instances of digression. The hearings, in particular, did not bear on the issue of priority setting among scientific fields and purposes. This is an area of such magnitude and importance it needs and deserves separate, thorough investigation.

Priority setting relates to peer review in at least two ways, neither of which was addressed during the course of the hearings. First, the Foundation may assemble a group of scientists (peers) to advise it explicitly concerning priorities. Second, the accumulated decisions on individual grants arrived at through peer review may constitute an implicit setting of priorities.

2. Selection of Witnesses

Two Congressmen asked to be permitted to appear as witnesses. Their requests were granted as a matter of course.

The Subcommittee strove to ensure that witnesses who appeared other than Congressmen either could provide expert knowledge concerning the allocation of funds for scientific grants or could represent the viewpoint of some segment of the scientific community concerning that allocation. In several cases witnesses embodied unique combinations of expertise and viewpoint.

The Subcommittee also wanted to be sure that responsible scientists with negative views on the Foundation were fully heard in order that critical comments might be evaluated. Representative Conlan was most helpful in this respect. He recommended seven witnesses all of whom were well-qualified scientists, and several of whom were leaders in their fields of specialty. In the interests of a full hearing, all seven were asked to appear. All seven were highly critical of one aspect or another of the Foundation's operation.

In light of the purposive selection of witnesses, it is clear that the record of the hearings should not be taken either as a cross-section of opinion from the scientific community or as a collection of disinterested expert testimony, but rather that the comments of each witness must be evaluated in light of the witness' background and the reasons why the witness was selected to testify.

A typology of witnesses according to the Subcommittee's reasons for selecting the witnesses follows, with notes on exceptional backgrounds:

TYPOLOGY OF WITNESSES

Picked for Competencies and Viewpoints

WORKINGS OF THE NATIONAL SCIENCE FOUNDATION

H. Guyford Stever, Director, NSF.
Norman Hackerman, Chairman, National Science Board.
Richard Atkinson, Deputy Director, NSF.
Donald Rice,[1] member, National Science Board.

OPERATION OF OTHER FEDERAL AGENCIES

John Sherman, former acting director, National Institutes of Health.
William Raney, Chief Scientist, Office of Naval Research.

ACADEMIC INSTITUTIONS

Universities: Charles Kidd,[2] Executive Secretary, Association of American Universities.

Small Colleges: James Powell, Provost, Oberlin College.

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[1] President, RAND Corporation.
[2] Author of a book on the conduct of Federal research grant programs.

SCIENTIFIC SOCIETIES

William Carey,[3] Executive Director, American Association for the Advancement of Science.

ENGINEERING VIEWPOINT

Donald Marlowe [4] (et al), Executive Director, American Society for Engineering Education.

WORKING SCIENTIST

Raymond Bowers [5], Professor, Cornell University.

REVIEWER OF ISIS PROPOSAL

Philip Morrison, Professor, Massachusetts Institute of Technology.

CONGRESSMEN WHO REQUESTED TO TESTIFY

John Conlan, of Arizona. Robert Bauman, of Maryland.

WITNESSES RECOMMENDED BY MR. CONLAN

MATERIALS RESEARCH VIEWPOINT

Doris Wilsdorf,[6] professor, University of Virginia.
Heinz Wilsdorf, department chairman, University of Virginia.
Rustum Roy,[6] department chairman, Pennsylvania State University.

BIOMEDICINE INNOVATION VIEWPOINT

Gilbert Ling, department director, Pennsylvania Hospital.
Carlton Hazlewood, associate professor, Baylor College of Medicine.
Freeman Cope, biophysicist, U.S. Naval Air Development Center Biochemical Laboratory.

CURRICULUM DEVELOPMENT PROJECT MONITORING VIEWPOINT

Elmer Seevers, science curriculum coordinator, Biomedical Interdisciplinary Curriculum Project.

3. Inquiry

The Subcommittee took pains to conduct a thorough inquiry into National Science Foundation peer review. Witnesses were questioned in depth routinely by Chairman Symington and by the ranking minority member of the Subcommittee, Charles Mosher of Ohio. Other Subcommittee members participated to varying extents in the questioning. As a result of the acceptance of all recommended witnesses and the detailed questioning of all witnesses, the hearings which were originally scheduled to last twelve hours spread over six days (July 22, 23, 24, 29, 30, and 31, 1975) in fact required a total of over 21 hours on those same days.

Following the hearings the Subcommittee, in addition to its own staff, employed the Congressional Research Service for a disinterested interpretation and evaluation of particularly technical testimony and asked the General Accounting Office to check the use by the Foundation of a particular collection of verbatim peer reviews.

For the hearings record, in addition to the spoken and written testimonies with their attachments, the Subcommittee solicited, received and inserted some two dozen further submissions and catalogued a like number of letters concerning peer review that it had received. A copy of the table of contents of the record follows:

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[3] Formerly a high official in the (now) Office of Management and Budget.
[4] Dr. Marlowe (et al) asked to testify.
[5] Also Director of the Program on Science, Technology and Society at Cornell University.
[6] Also member, NSF Advisory Committee on Metallurgy and Materials.

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III. Peer Review Systems

A. GENERAL

Most broadly speaking a "peer review system" is any method of evaluating a specialized creation—such as a proposal to perform scientific research—which involves having a group of people knowledgeable in the area of specialization evaluate the creation. The experts are called "peers," the term loosely deriving from the relationship between the proposer and the evaluators. In science the chief uses of peer review are to help determine whether a proposed piece of work or study should be funded or to help determine whether an existing scientific paper should be published. Peer review is used for these purposes because it is believed to be the best practical method of identifying excellence.

The Subcommittee's interest in peer review stems, of course, from its use by the National Science Foundation to evaluate proposals. Even in this more restricted sense, "peer review" is very broadly defined. Two particular pitfalls of definition should be borne in mind in any consideration of peer review. First, the label "peer review system" does not reveal who is actually making the decision on whether or not to fund a given proposal; it may be the group of peers, or it may be the person or organization controlling the money. Second, the "peers" involved in a peer review are often not the equals of the proposer. For example, proposals from postdoctoral students may be evaluated by full professors.

B. ELEMENTS

Following is a list of the most important elements used by Federal agencies in systems for deciding what extramural scientific projects should be supported. An agency will have established its programmatic priorities (including how much money should be spent on each program) by other means before reaching the point at which individual projects are considered. The list omits accounting and business reviews, which do take place. Consideration of a given proposal requires some, but rarely all, of the elements. Particular but differing patterns of use occur in differing agencies and programs.

1. Staff Judgement

In most systems agency staff judgement is a key element. At one extreme of reliance on staff in a peer review system, the staff may determine how a proposal will be reviewed, select the reviewers, use the reviewers only as advisors, and make the decision on funding. At the opposite extreme the staff may perform only clerical functions: mailing proposals to reviewers on a predetermined list, compiling evaluation scores, etc.

Staff judgement may be exercised by individuals or by panels of staff members. Grant review boards at the Foundation are examples of staff panels. Frequently, judgements made at the initial level by any procedure receive administrative review by an individual in the next hierarchical level (and possibly succeeding levels).

2. Individual Peer Review

Individual peer review occurs when an expert outside the agency staff evaluates a proposal without consulting other evaluators. Typically, copies of a proposal will be mailed to three to ten peers for individual peer review and returned to the agency.

3. Panel Peer Review

This may take several forms. Most commonly a group of experts meets together to consider the merits of a set of proposals. The panel may be a standing group (generally with rotating membership) or it may be an ad hoc group with a brief existence.

4. Site Visit

Site visits may be used in a variety of situations and may take a variety of forms. The site visit team may comprise a single staff person, several staff people, or a combination of staff and outside experts. A site visit may be necessary when the quality of scientific facilities at a site is a determinant of the likelihood of success of proposed research.

5. Policy Board

In some cases the question whether a given proposal fits into an agency's program is particularly crucial, or other policy difficulties may be raised by a proposal. In such instances the proposal may be referred to a policy board. An example is the National Science Board at the Foundation. Policy boards are usually standing groups with rotating membership.

6. Consultation With Other Funding Agencies

Consultation is frequently necessary. It is engendered by proposals requesting partial funding from various agencies, by requests for use of government facilities, by overlapping projects, etc.

C. NATIONAL SCIENCE FOUNDATION PEER REVIEW

The Subcommittee's focus in this report is on the National Science Foundation's methods for making individual awards. Either individual or peer panel review is used by the Foundation in the evaluation of the vast bulk of formal requests for funds. Hence, the Foundation's evaluation methods are generally called peer review systems. These methods were described in "Peer Review and Proposal Evaluation," a Foundation staff study dated June 1975, which is included in the peer review hearings record. Particular aspects of certain of the Foundation's procedures were described in greater detail during the questioning periods at the hearings.

In Fiscal Year 1974 about 21,000 actions were taken on project proposals submitted to the Foundation. Very nearly half the proposals were funded. Expenditures of $600 million were made for programs in that year by the Foundation. On the average each proposal received around 6 reviews. Roughly speaking, half the proposals received individual peer review only, a quarter received peer panel review only, and a quarter received both. The number of different reviewers was close to 30,000 and those reviewers submitted approximately 120,000 reviews.

The Foundation is unique among Federal agencies in its mission "to initiate and support basic scientific research and programs to strengthen scientific research potential . . ." (without regard to

applicability of research to immediate problems). The procedures of the Foundation for making awards have been largely shaped by its pursuit of this mission. Other missions of the Foundation are to support science education and to support immediately applicable research not adequately supported by other agencies. Decision-making procedures for awards stemming from these missions are different.

A summary of the Foundation's procedures for making individual grants follows. The summary describes only the mainstream of Foundation procedures. It is included here as a point of departure from which to interpret the issues and analyze the testimony. A deeper discussion of many aspects of the procedures is included in the "Analysis of Testimony" chapter of this report.

1. General

Given that the Foundation's priorities among programs and purposes have been established previously, the Foundation's methods for deciding who will receive an individual award begin at the point where it is decided what form an award will take. In the vast majority of cases, the award is a grant to or contract with an institution (which is financially responsible) to be used in the support by the institution of a project under the direction of a principal investigator (who is responsible for the work). A second type of award is for education (the Foundation's Graduate Fellowships are the foremost example), in which there is an institution and a person, but no project. A third type of award is a grant to an institution to improve the institution. The Foundation does not normally make: (1) awards to individuals in the absence of an institution to sponsor the individual, or (2) research grants to institutions for a particular scientist, not specifying that work in a particular field be done.

The Foundation acts on applications for funds in deciding who will get awards. These applications may be received unsolicited or may have been solicited by the Foundation from the scientific and technical community either in a request for proposals for undertakings in a given broad field (a program solicitation) or in a request for proposals to perform a project that has been defined by the Foundation.

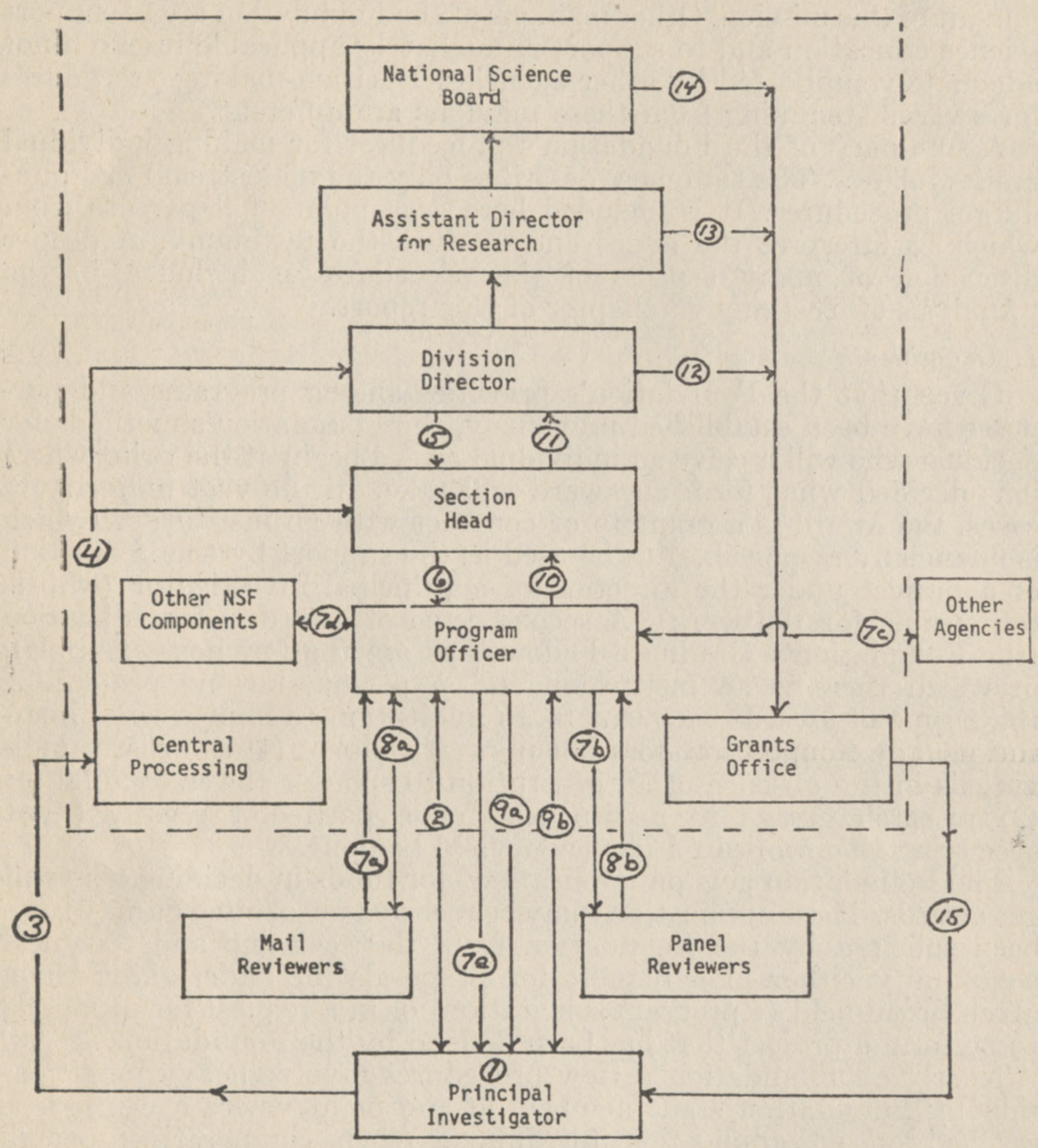
Nearly all Foundation review procedures involve heavy participation by Foundation staff members at the point where a decision is reached on an application for funds. When comparatively small amounts are involved in an individual award—as is the case for foreign travel awards—staff judgment alone may be deemed sufficient in arriving at a decision.

2. Basic Research

Over half the funds expended by the Foundation go for basic scientific research (over $300 million annually). Most basic research awards are for amounts in the range of $10,000 to $100,000. In addition to staff judgment, all basic research support programs use individual peer review for evaluating applications. The use of peer panels is mixed; fewer than half the Foundation's basic research programs use peer panels. Other review elements are employed in varying degrees by the various programs.

The following flow chart and list of processes show the procedures used in the evaluation of an application by the former Directorate for research. The procedures are still basically the same although the Foundation has reorganized.

Flow Chart of the Movement of a Research Proposal Through the Foundation



FOOTNOTES TO CHART

1. Principal Investigator (P.I.) conceives research plan.
2. P.I. may hold preliminary discussions with Program Director (P.D.) and/or submit preliminary proposal for evaluation.
3. Final proposal is prepared by P.I., approved by Institution and sent to NSF.
4. Central Processing assigns proposal to a Division.
5. Division Director assigns proposal to a Section.
6. Section Head assigns proposal to a Program.
7a. Program Director chooses reviewers and sends out proposal for independent mail review.
7b. Program Director may choose panel members and send them copies of proposal in preparation for panel meeting.
7c. Program Director may discuss proposal with another agency.
7d. Program Director may discuss proposal with other components of NSF.
7e. Program Director may make site visit (orsite visiting team may be appointed and report back to P.D.).
8a. Independent mail reviewers evaluate proposal and return signed, written reviews.
8b. Panel members discuss proposal and indicate rating.
9a. Program Director may decline proposal but suggest some major modification that would make it more acceptable or may suggest that a new proposal may be written.
9b. Program Director may decide to recommend funding and negotiates revised budget with P.I.
10. P.D. recommends funding of revised amount.
11. Section Head reviews recommendation, approves and transmits, or rejects.
12. Division Director reviews recommendation, approves and transmits, or rejects.
13. Assistant Director for Research may review recommendation.
14. If grant is large enough, National Science Board must review.
15. Grant is made to Institution, which disburses funds to P.I.'s project.

3. Research Applications

In recent years annual expenditures by the Foundation for applied research have been around $70 million. Most applied research grant amounts are in the range $40,000 to $400,000, thus averaging two or three times the size of basic research grants.

The Research Applications Directorate of the Foundation seeks to fund projects that will result in benefits soon after completion. Usually, the Research Applications Directorate has a particular benefit in mind and applications are solicited for projects generally designed to achieve a known goal (a program solicitation). In some cases, the project necessary to achieve a benefit can be described beforehand and the Foundation will issue a "request for proposal" (RFP). The Foundation must also deal with unsolicited proposals for applied research which do not fit its predesigned programs. Thus, three different types of proposal solicitation and evaluation are used by the Research Applications Directorate.

1. Proposals submitted under program solicitations are screened by the staff. Those judged by the staff to be above a minimum quality level generally receive peer panel review. The peer panel commonly considers a batch of proposals addressed to a given program solicitation and makes the primary decision. The decision is reviewed at higher staff levels.

2. The evaluation of proposals submitted in response to an RFP is closely governed by Federal regulations. Primary decision-making on such proposals in the Research Applications Directorate lies with a panel usually composed of scientifically or technically qualified Federal employees.

3. An unsolicited proposal is generally discussed with the Foundation's program manager before being submitted; this constitutes a pre-review. A formally submitted unsolicited proposal will receive individual peer review. The staff makes the primary decision, which is reviewed at higher staff levels.

4. Education

Two quite dissimilar types of application are handled in the Education Directorate: fellowship applications and project support applications.

About $15 million is spent annually for fellowships at an average expenditure of somewhat less than $10,000 each. Fellowship applications are reviewed and evaluated by ad hoc panels. The primary decision lies with the panels themselves.

The Foundation's expenditures for other science education activities are of the order of $50 million annually. Project support applications are received in several different Education Directorate programs. About three-fourths of such applications are evaluated through ad hoc peer panel review. Standing peer panels are not used. Approximately a fifth of the Directorate's proposals receive individual peer review.

5. Other

National and Special Research programs of the Foundation have required around $90 million annually (the Ocean Sediment Coring Program excluded). The Foundation's methods of reviewing proposals in these programs vary widely. Individual peer review is the most common adjunct to staff review. The programs usually last many years. This allows the evaluation of new proposals to lean on reports of work already performed.

National Research Centers (plus the Ocean Sediment Coring Program) expend about $60 million annually. The Centers are each funded by the Foundation through relatively few, but large, contracts. In its decision-making with respect to the Centers, the Foundation appears to determine how much it wishes to spend on the Centers as opposed to other programs, not as opposed to other projects. Hence, decision-making on Center funding falls outside the scope of this report.

D. OTHER

Many Federal agencies make awards for basic scientific research. Representatives of two such agencies, the National Institutes of Health and the Office of Naval Research, appeared at the hearings and presented the methods used by those agencies to decide to whom awards will be given, as a contrast to the procedures of the National Science Foundation. The Subcommittee used this testimony to understand what differences in mission or environment would explain the differences in procedures of various agencies.

1. National Institutes of Health

The mission of the National Institutes of Health (NIH) is the conduct and support of research to enhance the understanding of health and disease so as to improve the health and well being of the people of the nation. NIH both operates its own laboratories, clinics, etc. and supports the performance of scientific projects by other institutions, chiefly universities. NIH has a program of extramural contracts and a much larger program of extramural research grants. The Subcommittee focused its attention on the extramural research grant program.

In Fiscal Year 1974 NIH disbursed $569 million for about 11,000 extramural research grants to nearly 1,100 institutions. In that year the NIH research grant program considered 10,000 new applications; slightly fewer than half were funded. An additional 6,600 applications for continuing funding for previously approved projects were approved as a matter of course.

NIH procedures for deciding who will receive research grants are more regular than those employed by the Foundation. The procedures were described in the testimony of Dr. John Sherman, former acting director of NIH, which appears in the peer review hearings record.

Peer panel reviews by standing "study sections" with rotating membership are employed as the key decision-making element in the NIH system. In addition to peer panel review by study section, applications recommended for approval by the study sections receive policy board review by an advisory council (one council is mandated by law for each of the eleven NIH institutes). This policy board review changes the status of a proposal in comparatively few cases.

Currently NIH maintains about 50 study sections, each of which has 16 or so members (the total number of peer reviewers used annually by NIH to help judge research grant applications is thus around 1,000). NIH does not find it necessary routinely to publish program solicitations in order to obtain adequate grant applications. The field of science covered by the interests of the eleven institutes is very broad, and the community of applicants is able to address those interests effectively in its unsolicited applications. When an application is received a central office assigns it to both a study section and an institute.

Most study sections are apt to review proposals for several institutes although some relate primarily to a single institute. Each study section is served by a full-time NIH employee called an executive secretary (corresponding roughly to a Foundation program director). Study sections normally meet three times annually and consider a batch of applications at each meeting. The executive secretary is responsible to see that sufficient information is available about each application. A site visit or individual peer reviews may be employed in infrequent cases, the results of which are provided to the study section to aid in the evaluation of an application.

Each application considered is recommended for approval or disapproval or is deferred for further collection of information at the study section meeting. Approved applications receive a numerical priority rating based primarily on scientific merit, and a summary statement is prepared based on the written reviews and comments of study section members. The primary determinants of whether a given proposal will be funded are its priority score and the amount of funds available in the institute of NIH to which the proposal has been assigned. The priority rankings of the study sections are used to prepare a priority-ordered list of proposals (which may involve projects reviewed by several study sections) for presentation to each institute advisory council. The council may change the list to conform with institute programmatic policies. As noted earlier, changes are not usually extensive. Grants are made in each institute according to the priorities agreed upon by the advisory council until the institute's research funds are exhausted, but by law, no grant may be funded unless recommended by the council. Currently, from 13 to 60 percent of approved proposals are funded, depending upon the institute.

2. Office of Naval Research

The mission of the Office of Naval Research (ONR) as described in its statutory authority and executed by ONR, is "to plan, foster and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security." Like NIH, the Navy has extensive in-house laboratories but supports extramural research as well (the similarity does not extend much farther). ONR supports extramural research for the good of the Navy rather than for the general national good. Nevertheless, much work ONR supports is basic research.

ONR distributes roughly $60 million annually for scientific research awards. Contracts rather than grants are used as the award instrument, but the type of award seems not to have much interrelationship with the decision-making process that leads to the award.

Methods used by ONR to decide who will receive awards were described at the peer review hearings by William Raney, Chief Scientist at ONR. The key element in the ONR decision-making process is the ONR staff. ONR "scientific officers," the counterparts to the Foundation's program officers, are expected to maintain a strong orientation towards serving the needs of the Navy. ONR establishes programs designed to meet perceived Navy needs and publicizes its programs for the benefit of potential applicants in *Opportunities for Naval Research*. ONR interests are also made known through sympo-

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sia, workshops, etc., and the contacts of ONR scientific officers with the research community.

The scientific officer is also dominant in the proposal review part of ONR's decision-making process. The scientific officer determines how each proposal will be reviewed; there is no ONR-wide approved method. At the discretion of the officer, individual peer review or panel peer review may be employed—and have been employed in many instances. Alternatively the scientific officer may make a decision himself or herself or call on other Federal agencies for advice, or undertake different types of review, as deemed appropriate to the particular situation.

3. Scientific Articles

Most professional journals and many scientific and technical magazines use a peer review procedure to select papers or articles for publication from among unsolicited submissions of the interested community. The journal editor mails copies of a submitted paper to one or several reviewers who read the paper, edit and/or comment on it, and return it. The editor decides whether to print the paper largely on the basis of the reviewers' advice. Reviewers' comments are normally made available verbatim to the author with the reviewers' names deleted.

Several witnesses referred to their experience as editors with peer review. There are essential differences between the review of a paper and the review of a proposal, however, which limit the validity of comparing the two uses of peer review. Foremost among the differences is that a paper is a finished piece of work and may be evaluated with much less regard to the scientific ability of its author than a proposal. In some fields papers are reviewed with the author's name deleted; a proposal evaluation, on the other hand, always requires the reviewer to judge the applicant.

IV. Issues

Peer review provides a wealth of issues. The issues, moreover, are not discrete but interact strongly with one another. They may be cast in four constellations and a group of miscellany. The four broad areas are:

Does the National Science Foundation support high-quality research?

What do all the people involved in the Foundation's decision-making processes do? Are they doing the right things, and are they doing them right?

How open and fair is the Foundation's system of making awards?

What distribution of money results from the Foundation's decision-making processes? Is it desirable?

A. SUPPORT OF HIGH-QUALITY RESEARCH

The most important single consideration is whether the National Science Foundation's awards lead to the advance of science in the most effective possible way. Regardless of any other factors, if the Foundation is not supporting good research and education, it is not fulfilling the charge Congress has given it. How do the Foundation's decision-making procedures relate to this charge?

In this issue it is useful to distinguish between research that is good but orthodox and research that is innovative (and good).

1. Generally Good Research

Do the Foundation's decision-making procedures lead to the support of projects at the upper end of the quality scale? Would other procedures select better projects? In an absolute sense how high is the average quality of the funded projects?

2. Innovative Research

The most significant advances in science, those associated with names like Darwin, Einstein, Freud, Galileo, and Pasteur, challenge the mainstream of scientific theory or religious or philosophic belief. The Foundation's procedures for making awards should not prevent the Foundation from supporting innovative theories. Large innovations provide the girders that structure science. Research that is good but not innovative is the mortar and bricks that fill in the gaps. Without innovations, good research runs out of gaps to fill, and science is more limited than nature would allow.

Does the Foundation adequately support innovative research?

B. MANAGING PEER REVIEW AT THE FOUNDATION

1. Management Policy

How are the basic policies for the Foundation's decision-making procedures established? Who should be establishing the policies: Congress, the National Science Board, or the Foundation staff? Are the present policies adequate?

2. NSF Staff

What role does the Foundation's staff play in the decision-making process? Is it a practicable role? Do the Foundation's staff members perform their roles in an honest, competent way, in accordance with Foundation policies?

3. Reviewers

What role do reviewers play in the decision-making process? Is it a practicable role? Are they conscientious, honest, and competent?

The most common objection to the use of peer review is that it is subject to "backrubbing" or "old boys clubs," in which mutual friends unduly praise each other's proposals. To what extent does this happen?

Are reviewers selected fairly and rationally? What is the distribution of reviewing among potential reviewers? Is this an appropriate distribution?

Are reviewers utilized in the most effective and fair manner? In particular, should the mix of individual review and panel peer review have its proportions changed? Suggestions have been made from several quarters that reliance on panel peer review should be increased.

4. Division of Responsibility

In most decision-making systems for scientific awards it is possible to identify a point or interval in the flow of events where the decision is actually made. This key point is likely to be preceded by advisory activities and followed by checking activities, but rarely is the decision-making smeared out along the whole process.

Should this key point be moved closer to the Foundation staff or closer to the reviewers? Should the key point be spread out more along the process?

5. Policing the System

Is the Foundation's decision-making system for individual awards working as it is supposed to work? What ways are available to determine the answer to that question? What is the role of trust vs. policing in keeping the system working?

6. Congressional Oversight

During the authorization of the Fiscal Year 1976 National Science Foundation budget, the House of Representatives voted at one point to require Congressional review of individual research awards. The Senate objected to this requirement, and it was eliminated from the Foundation's authorization bill in the conference agreement on the bill.

The Subcommittee addressed the question once again: should Congressional review be required before individual National Science Foundation awards are made?

C. INFORMATION EXCHANGE AND APPEALS

1. Degree of Openness

Independent of its effect on the grant application decision-making process, to what extent is openness of the process desirable? How far can openness coexist with the effective evaluation of applications? In particular, should the applicant be provided with verbatim reviews of the application or with the reviewers' names?

2. Feedback to Applicants

What information should be provided to an applicant concerning the process that led to the Foundation's decision on his or her application?

3. Appeals

Should the Foundation have a more formal means of reconsidering its decision on an application than it has now?

D. DISTRIBUTION OF FUNDS

The law regarding NSF provides that "it shall be one of the objectives of the Foundation to strengthen research and education in the sciences, including independent research by individuals, throughout the United States, and to avoid undue concentration of such research and education."

What, in fact, is the distribution of the Foundation's funds? Are there "undue concentrations"? To what extent is the distribution of funds a result of peer review procedures? If there are imbalances, how should they be corrected?

1. Geographical

What is the fair way to measure the concentration of research and education on a geographical basis? Current funds are commonly accepted as a surrogate for "research and education," and the State is commonly accepted as a geographic unit, but to what demographic feature of the State, if any, should the distribution of funds for that State be proportional? Population, number of scientists and engineers, and many other measures have been suggested. If some kind of proportionality is judged desirable, how far from exact must the proportions be to become "undue?"

Is the law regarding "undue concentration" still the will of Congress?

2. Institutional

Are proposals from the faculty of undergraduate institutions fairly considered relative to those from the faculty of graduate institutions? On the graduate level, does the reputation of the proposer's institution have too great an influence on the decision to fund a proposal?

3. Young Scientists

It is frequently said that scientific research is a young man's game. Are young scientists adequately supported by the Foundation?

E. OTHER

Several issues were discussed at the peer review hearings which were tangentially related or unrelated to peer review.

1. National Science Foundation Programs

Three specific Foundation programs were addressed by different sets of witnesses: materials research, engineering, and biochemistry.

2. Overlap of Research

To what extent does the Foundation support research in areas of interest to other agencies which also support research? Is this state of affairs desirable?

V. Analysis of Testimony

A. SUPPORT OF HIGH-QUALITY RESEARCH

Witnesses agreed overwhelmingly that some form of peer review should continue to be used to assist in the allocation of Federal funds for scientific research. Not a single witness suggested that peer review be abandoned, although several witnesses proposed changes in the decision-making processes of the Foundation—some minor and some major in their potential effects.

1. Generally Good Research

The basic rationale for the use of peer review in decision-making for scientific awards is that the experts in a field of science are better able to judge several important factors than anyone else. These factors include:

Past performance of the proposer.
Design of the proposed work.
Importance of proposed work to the scientific field.

In particular, most witnesses agreed that the NSF staff could not perform as well without the benefit of peer review as with it. Indeed, several witnesses stated that the potential for staff abuse is greater in systems lacking peer review.

There was not a great deal of testimony addressing directly the issue of the quality of projects supported by the Foundation. It may be fairly inferred from the testimony, however, that witnesses agreed almost unanimously that appropriate peer review procedures would tend to select for funding those projects at the upper end of the quality scale, however high or low the upper end might be. Of the witnesses who addressed quality directly, most minority witnesses said that certain NSF-supported projects were poor; all other witnesses said NSF-supported projects are generally good.

The following quotes from the record reflect witnesses' direct statements about the usefulness of peer review. Many of the witnesses quoted below also suggested changes in the Foundation's use of peer review, but no witness made statements contradictory to those below.

Raymond Bowers:

The assessment and maintenance of quality is of fundamental importance to scholarly activities and institutions. Peer review is the principal procedure used for quality control. (459)[1]

I have experienced greater problems with a few program officers, who have very strong opinions about how research should be conducted. The results of peer review act as a restraining influence on such officials. (460)

William Carey:

In its general design and structure, as well as its purposes, the peer review procedures seem to me to be a sensible and practical way to validate the scientific merit of research proposals . . . I believe that our expectations of peer review as to efficiency, reliability, and quality control should be tempered (however) by realism. (774, 775)

[1] Numbers in parentheses following quotes are page numbers of the pages in the hearing record where the quotes are to be found.

Norman Hackerman:

Review by peers brings to the (National Science) Board's oversight function, as well as to staff review, distinct benefits in judging the quality of the proposed research and the qualifications of the principal investigator. It strengthens the decision process by providing the knowledge of the scientists working at the forefront in the field to complement the competency of the staff of the Foundation and the Board. (74, 75)

Philip Handler:

Whereas programmatic decisions with respect to the details of programs of technology development and of most programs of applied research must be made by mission-conscious, agency program managers, the principal directions and thrusts of federally-supported fundamental research are necessarily dictated largely by the progress of science itself, as perceived by scientists and expressed in the research proposals of individual scientists. (987)

Virtually all who have participated in or examined the operation of the research project grant award system have concluded that it is critically dependent upon the use by the agency staff of expert advisors to help identify the scientifically most meritorious projects for support. No matter how knowledgeable, sophisticated or talented the federal administrator, even at the time of his initial appointment, it is highly unlikely that he can, unaided, adequately evaluate and compare the merits of the diverse research proposals which will confront him. (990)

As we have seen, it would be difficult to support a contention that the peer review system, as practiced at the NSF, has not performed well over the past 25 years . . . Yet, one senses a growing concern that the peer review system be examined and, perhaps overhauled. (991)

Vincent Haneman:

Second, the peer review system used to evaluate proposals has a number of problems, but it does provide a strong motivation and drive toward excellence. As far as I have been able to determine, it is far better than any other method we can devise. (614)

Charles Kidd:

Colleges and universities strongly support the peer review system for a number of reasons. (472)

In conclusion and in response to the basic question as to the worth of the system, peer review is a proven and valuable part of the American scientific scene. It should continue. (475)

Gilbert Ling:

The third part is to emphasize that peer review is not just a lot of faults and no merit. Indeed, it is a good system in many ways. . . . What is really seriously missing is an appeal system. (877)

James Powell:

The principal advantage of the peer review system is that research proposals are judged on their scientific merit by those who have the most information on which to base their judgement: practicing research scientists. (428)

Guyford Stever:

I still remain convinced that NSF's peer review system is a fundamentally sound method for providing a broad base of scientific judgement in the decision process. (901)

Doris Wilsdorf:

I am a strong advocate of the . . . peer review system . . . I am trying to convey so strongly that if the peer review system is objectively administered, it can do beautifully. If not, then, obviously, it can do anything. (748)

2. Innovative Research

Many witnesses and Congressmen attested to their conviction that innovative research should be supported. No one spoke against this notion.

While many witnesses avowed that peer review results in the support of high-quality research, some of which is truly innovative, there was not much confidence expressed that peer review consistently leads to the support of innovative research if it challenges the mainstream of scientific thought or if it seems unlikely to succeed. Arguments and the weight of opinion to the contrary were rather persuasive.

Since no objective data were presented pertinent to this issue—largely, it is believed, because such data are rare and hard to interpret—the Subcommittee has had to rely on argument and opinion.

The argument that the National Science Foundation does support innovative research is that program managers seek to fund excellent proposals, and "nobody wants to turn down the next Nobel prizewinner."

Arguments that peer review does not lead predictably to the support of innovative research if it is challenging or risky are roughly as follows:

If a proposal challenges the mainstream of scientific thought, the expert peer reviewer who is the mainstream will tend to see the proposal as wrong on the face of it. The expert reviewer, in particular, is likely to have worked on experiments which either assumed the mainstream hypothesis to be correct or which tested and corroborated the hypothesis. The reviewer's self esteem and reputation in the scientific community may therefore depend upon the correctness of the mainstream of thought. Moreover, the reviewer's laboratory facilities and Foundation grant may be proven useless if the innovative hypothesis is correct. Thus, it may be contrary to the reviewer's interest to find merit in the proposal.

Evidence in the form of personal experience, purporting to show that the Foundation failed to support a correct but challenging innovative theory was given by Drs. Ling, Hazlewood, and Cope. The scientific dispute on which their testimony was based has not yet been resolved in the scientific community.

Evidence supporting the argument that the scientific community believes peer review often fails to lead to the support of challenging innovative research was presented by two witnesses in the form of separate Industrial Research Magazine polls. While both polls are extremely suspect because of the miniscule response rates (less than 5%), and selection of potential respondents by criteria completely different from those one would use to obtain a cross-section of the scientific community (the criterion was that the respondent received the free magazine *Industrial Research*), no evidence to the contrary was introduced or even mentioned.

Some witnesses said that proposals combining high potential scientific payoff with low chance of success should be funded selectively but would be underfunded because both program managers and peer reviewers would be unwilling to risk failure. This would occur whether or not the proposals were challenging to the mainstream of thought, witnesses implied.

The issue of innovative research is not self-contained. It is tied strongly to (1) appeals to Foundation award decisions, (2) overlap of research areas supported by Federal agencies, and (3) Congressional review of research grants. The arguments are:

1. An appeals process would help insure that worthy innovative proposals are funded.

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2. As long as several Federal agencies are supporting research in a field, chances are that at least one of them will support a worthy innovative proposal. This has happened in the case of Dr. Ling, who was funded by NIH after the Foundation turned down his proposal.

3. Congressional review of research grants would likely stifle innovation.

Further explication of these arguments is given in other parts of this analysis of testimony.

Need for Innovative Research

William Carey:

I believe it (peer review) should seek to strengthen American science and our ideas of opportunity and fairness, by providing some incentives for reviewers to look for new and promising scientists just entering the research profession, and for new ideas which involve genuine risk taking. (782)

Philip Handler:

As has been so frequently noted, "In science, the best is vastly more important than the next best." One cannot sum several mediocre projects in order to gain the equivalent of one superlative effort. . . .

The scientists in the very good and good categories greatly outnumber those whom we might regard as Excellent. Their research contributes the bricks and mortar with which the house of science is built; the relative handful of Excellent scientists are, in effect, its architects. (989)

Guyford Stever:

A number of witnesses at these hearings have expressed concern that the system may be biased against the really innovative proposal, one that goes against the tradition in its field and which could lead to a major conceptual breakthrough. This is a concern that I share, as do the NSF program officers and most reviewers of proposals. No one would like to think he had turned down or recommended turning down the next Nobel laureate. (903)

Support of Innovative Research

Richard Atkinson:

I do feel that the maverick in our system, the person who really has an idea that is counter to what most of the scientific community believes, is going to receive very special treatment in our system. If anything, I think our system leans over a little too far in the direction of trying to favor the maverick . . . I think Copernicus or Galileo would have been sought out by program officers at the National Science Foundation and would have been funded, but they would have been watched very carefully. (285)

Robert Bauman:

Is it possible, in other words, that NSF policies actually discourage innovative and creative scientific efforts? . . . in the correspondence I have received there have been a number of instances of charges from some of NSF's past recipients, at least they identified themselves as such, saying just about what I passed along to you, that new ideas are being stifled by NSF. (202)

William Carey:

I suspect that, under severe rationing conditions, risk-taking tends to suffer. Whether my suspicion is well-founded, I am unable to say, because nobody seems to analyze the output of the peer review process with this question in mind. (776)

Carlton Hazelwood:

The present method of peer review contains in my opinion, a natural bias against revolutionary ideas and findings. In my testimony I present three major criticisms of our system and present a possible solution. One, grant proposals are evaluated in terms of established concepts. Two, peer reviewers are not neutral parties necessarily but have vested interest in the outcome . . . three, no higher court of appeals exists. (863)

B. MANAGING PEER REVIEW AT THE FOUNDATION

At the outset it must be observed that any system used by the Foundation for evaluating applications for scientific awards is apt to displease many competent scientists. The problem was clearly enunciated by

Philip Handler:

> (A) growing fraction of all worthwhile research proposals is rejected annually for lack of funds rather than lack of scientific merit. Under such circumstances, it is inescapable that there will be competent scientists complaining that the peer review process did them an injustice and alleging bias or other shortcomings in the system. (992)

Another facet of this problem is that if a project cannot be executed for lack of funds, the thought and time that went into the project's planning is wasted.

Rustum Roy:

> I think today that the . . . peer review system is approaching a dangerous level of inefficiency. We waste more time using up the best brains of the country in writing their own proposals. (754)

Both of the above quotes would extend to any evaluation system for project proposals. Research support outside the *project* system might avoid project evaluations altogether, but the Subcommittee believes project support (as opposed to blanket funding, or supporting individuals) is still far the best mode for distributing the bulk of Foundation funds.

1. Management Policy

Not much testimony was explicitly directed towards the matter of who should set policies for peer review at the National Science Foundation. The Director of the Foundation, it may be inferred, is a principal actor in policy determination. National Science Board members Norman Hackerman and Donald Rice noted the responsibilities of the Board for setting policy and explained the Board's present policy interests. Congressmen John Conlan and Robert Bauman made it clear they felt Congress should play a strong role in policy determination. All other Congressmen who spoke to the issue felt Congress should be somewhat more distant. A further look at testimony concerning Congressional involvement appears later in this analysis of testimony.

William Carey:

> I do not suggest a "manual of instructions" because I think such things are generally deadly and counterproductive, but I do believe that top management should make clear, in writing, the role of peer review in decision-making and its expectations as to the uses and the limts of peer review. This is the very least it can do, and there is every reason for sharing these statements with the scientific public so that each side knows where it stands. (781)

Norman Hackerman:

> The National Science Board was charged by the Act (governing the Foundation) with responsibility for establishing the policies of the Foundation to carry out . . . provisions of the Act. (71)
>
> (T)he Board reviews from time to time the award decision-making procedures of the Foundation, including the solicitation of opinions from the scientific peers of the investigator requesting support, the role of the scientific staff of the Foundation, and the role of the Board itself. (76)

Philip Handler:

On the other hand, it would be useful if the National Science Board would prepare a comprehensive statement of the philosophy, policies, and procedures governing the NSF peer review system, a statement that would be informative and instructive to the grant applicant, the Congress and the interested public. (998, 999)

Donald Rice:

The Board is continuing its examination and oversight of the award decision-making process with the intent of making it the most effective, fair, and credible system we can devise. (769)

James Symington:

The role of Congress and this committee is and has been to review the program and budgets of the executive agencies. Necessarily, the emphasis in this process is upon the major objectives of managerial performance and program achievement. (878)

2. NSF Staff

a. Role

The Foundation's staff plays a key role in the decision-making process for individual awards. Staff responsibilities characteristic of most Foundation decision-making are:

(1) Selecting reviewers and soliciting reviews.
(2) Using the reviews as advice.
(3) Making the initial funding decision on a proposal and reviewing the decision.

There are extremes of difference within the Foundation from this set of responsibilities (for example the processes used for graduate fellowships, international travel grants, and national research centers are quite dissimilar), but the bulk of decision-making finds the staff in the characteristic role.

From the witnesses' testimony it may be concluded that the role of Foundation staff members described above has proved practicable in that it does result in decisions being made, expert advice has been used in the process, and comparatively few complaints about the outcome of the process have been voiced. There were many suggestions for changes in the staff role, however. These are discussed later in this report.

Because the Foundation's staff has been a key determinant of the Foundation's performance heretofore, and changes in staff responsibility lead to changes in staff morale in the short run and staff capability in the long run, it is evident that the effects on the staff of any redistribution of responsibility should be carefully considered and monitored.

b. Overload

Several witnesses noted the size of the workload on Foundation staff members and said it represents an overload in that it would not be possible to give sufficient attention to each proposal. In the basic research directorate, for example, a program director will act on 50 to 250 proposals annually. Section heads, the immediate superiors of program directors, review in the neighborhood of 300 recommendations to fund proposals each year.

The Foundation observes a continuing general increase in the quality of proposals it receives. Whereas separating the wheat from

the chaff sufficed in former years, in the face of better proposals and limited funds, it is now a question of separating the good from the excellent, a more time-consuming task. As a result there is frequently a long delay between the submission of a proposal and a determination of whether it will be funded. The number and length of delays may become a serious problem, or perhaps the problem already exists.

No witness suggested an increase in the size of the Foundation staff to counteract the overload problem.

William Carey:

Times have changed. The traffic of proposal business now clogs the arteries, and in trying to move this traffic there are bound to be heavy strains on the system. Matters are further complicated by the need to ration limited funds, and this intensifies the problems of choices and equity. The expansion and diversification of science, fed for decades by Government stimulation, has had the effect of multiplying opportunities for good research and the number of scientists capable of doing the work. Budget economies have denied agencies like NSF the manpower to stay on top of workloads and to monitor ongoing research, and at the same time navigate the sea of new proposals and renewals. All of these considerations cause me to suspect that the peer review system is under far more pressure than it was designed for, and the only surprise is that it has not collapsed. On the whole, it has held up extremely well. (775)

c. Performance

Testimony concerning the honesty and competence of the Foundation's staff was mixed but on the whole moderately supportive. Rep. Conlan was extremely critical of the staff in these respects. His views were supported only by certain of the witnesses he asked to testify. Other witnesses generally held the Foundation's staff in high regard. Letters received by the Subcommittee tended to be supportive of the Foundation's staff.

It was suggested by Rep. Conlan that Foundation program managers know the reviewers they use well enough for the manager to get any response he wants on a proposal by selecting the right reviewer. Several witnesses addressed this specific point in response to Members' questions. The result was that all who expressed an opinion thought it would be possible for program managers to do this, but so far as any witness knew, it was not being done. Several witnesses felt, however, that the possibility of this type of manipulation should be eliminated anyway.

Mr. Symington:

The question is whether the program directors have programmed the entire series of decisions through the selection of the peer reviewers.

Dr. Roy:

My position is that it is certainly possible . . . I don't have the data at this time to say this has been done within NSF. (762)

Mr. Symington:

(Do) program managers know how to manipulate the reviewers to get the answers back that they want, by knowing who the reviewers are and what biases they have.

Mr. Carey:

I think it is possible for program managers, indeed, to manipulate the system . . . I have no personal evidence of this happening, but I quite agree that that it is possible. (778)

Two specific allegations of lapses in staff performance were made by Rep. Conlan: the case of the Individualized Science Instructional System (ISIS) and the proposal of Ahmad Shouman.

d. ISIS

The essence of the allegation in the ISIS case is that the Foundation's staff willfully misrepresented the peer reviewers' comments on the ISIS proposal when the proposal was presented to the National Science Board in order to ensure that the Board would approve. The implication was made that the proposal would not have been funded if the reviewers' comments had not been misrepresented.

The Subcommittee is conducting an investigation of the ISIS case through its staff and with the assistance of the General Accounting Office. The investigation is not yet complete. The Subcommittee plans to make a statement about its investigation of ISIS at a later date.

e. Shouman

The basic point made concerning the Shouman proposal was that the Foundation's staff officer handling the proposal acted autonomously in a manner not in accordance with then-existing Foundation policy. The Foundation admits that the staff officer did send verbatim reviews to Dr. Shouman, which at the time was contrary to policy. The staff officer involved was transferred out of the Foundation some time ago in a transfer having no connection with the Shouman case.

3. Reviewers

a. Role

The role of peer reviewers used by the National Science Foundation is straightforward and has proved practicable during the last 25 years.

An individual peer reviewer normally receives in the mail a single proposal to review. The reviewer then studies the proposal and other material if necessary, writes a review of one or a few pages, and mails the review back to the Foundation with the (possibly marked) proposal.

The review of a proposal will normally take into account the technical adequacy of the proposal, the importance to science (or to the solution of a real-world problem) of the proposed work, and the likelihood of success by the proposer (generally called the principal investigator (PI)). Past performance of the proposer is taken into account, particularly in judging the likelihood of success.

Peer panel reviewers normally each receive in the mail a number of proposals in one batch to review. Frequently a particular reviewer will be asked to read all proposals in a batch, but will only review selected ones in depth. Following this private review, the panel will meet and each proposal will be discussed. A rating of each proposal by the panel as a whole will normally be generated—either by panel agreement or by some balloting procedure. Depending upon the format of the panel meeting, the panel's rating may be morally binding on the program manager to a greater or lesser extent.

b. Merit

The outstanding merit of employing peer review for the evaluation of applications for scientific awards is that the highest available expertise is applied to the evaluation. The scientific community has

accepted peer reviewing as a professional obligation. The Foundation reports that 92 percent of the reviews it requests are performed. Peer reviewers are normally reimbursed by the Foundation for expenses incurred in reviewing (usually nothing for individual reviewers, travel and living expenses for panel reviewers who must get together), but normally receive no payment for their reviewing services. The value of an average review, were it paid for at a rate reviewers might charge if they were acting as consultants, would likely lie between $20 and $100. The value of the roughly 100,000 reviews contributed free to the Foundation by the scientific community each year is thus in the range of $2,000,000 to $10,000,000. Reviewers do derive non-monetary benefits from reviewing, but these are impossible to quantify. One benefit is that the reviewer discovers the research ideas of someone else in the field. Over an entire scientific subcommunity the reviewing system thus acts as a DEW line for scientific discoveries. A second benefit to the reviewer is that the Foundation program manager learns something about the reviewer's capabilities and performance.

c. Bias

The principal drawback to the use of peer review for the evaluation of applications for scientific awards lies, as several witnesses said, in the potential for biased evaluations by the reviewers. The most frequently cited form of potential bias arises from the existence of "old boys clubs," groups of people in a discipline who know each other. It is alleged that members of such groups will praise each others' proposals unduly, and downgrade outsiders' proposals unduly. This behavior might be either intentionally self-serving or the result of a view of the discipline common to the group's members.

Other forms of reviewer bias mentioned by witnesses included bias against someone a reviewer knew and disliked or disagreed with, or favoritism towards personal acquaintances to the disadvantage of strangers simply by virtue of being able to make a better-informed judgment.

Neither the problem of bias nor the following question of overconcentration of reviewing is easily addressed. Despite wide agreement that "old boys clubs" could occur and probably had, not a single example of an "old boys club" was mentioned.

The reasons for difficulty in determining bias are:

1. Most importantly, talent is concentrated. In most fields of science there are a handful of acknowledged centers of excellence. Talented people frequently move to such centers, and the centers actively recruit talent from wherever they can find it. Not surprisingly, reviewers at these centers tend to rate proposals from other centers highly.

2. In any scientific specialty practitioners of the specialty are extremely likely to know one another and have some easily describable relationship such as: "They both went to Stanvard" or "their advisors were roommates at Harford."

3. Reviewing scientific proposals is an extremely subjective matter. It is not possible to take a proposal, stick it into a machine, and get a quality rating. If it were possible, peer reviewing would not be necessary.

d. Distribution

A second question about the Foundation's use of reviewers, implicit in the testimony of some witnesses, is "Does the Foundation use all the competent potential reviewers." It was agreed by all who addressed the

question that reviewing should not be concentrated in the hands of a small portion of the competent community. The obverse of this point is that neither should the reviewing be spread so thinly that no scientist can become a proficient reviewer. Reviewing, like most other human skills, may be improved through practice.

The concentration of talent mentioned above is also the principal difficulty in judging the appropriateness of the distribution of reviewing.

Data presented by the Foundation concerning the utilization of reviewers was highly aggregated and, therefore, provided only modest illumination of the issues. The Subcommittee believes the data do show that reviewing for the Foundation is not intensely concentrated but do not reveal whether the distribution of reviewing is sufficiently broad. No one has suggested it might be too broad already. The Foundation's 300 or so program managers used about 30,000 different reviewers in Fiscal Year 1974 who performed about 120,000 reviews altogether. The number of science and engineering doctorate holders in the United States is about 240,000.

Roughly speaking, then, each Foundation program manager uses an average of 100 reviewers each year, each of whom performs 4 reviews, but only one in eight doctorate holders performs reviews for the Foundation each year. These derived figures should not be used or expected to approximate the analogous figures for any given Foundation program; the aggregated numbers blur many unique situations.

No data or other evidence was presented to indicate how much change there is from year to year in the set of reviewers used by the Foundation. The Subcommittee does not doubt that the membership of standing peer panels used by the Foundation rotates, but is uninformed about rotation of individual peer reviewers and ad hoc panelists.

DISTRIBUTION OF REVIEWING

Raymond Bowers:

The recent decision of the National Science Board to make available lists of reviewers used in the various scientific areas is constructive. It would be desirable to require the agencies to maintain a steady turnover of reviewers. (461)

Charles Kidd:

Membership on peer review groups or panels should rotate. No one questions the necessity of rotation of membership when formal "outside" review groups are used and the reviewers are appointed for fixed terms. What is required is a reasonable balance between rotation at a relatively rapid rate in order to expand the number who serve as reviewers and rotation at a rate slow enough to allow reviewers to become familiar with the review system. (474)

James Powell:

I would like to close with four specific recommendations which we believe would improve the peer review system. For research proposals: One, review panelists should include highly qualified scientists from undergraduate institutions as well as ones from graduate institutions. (445)

Several different modes of reviewing were proposed by witnesses, and discussed in some detail. Each of these modes is connected to several issues. The suggestions deserving serious consideration were: blind reviewing, the creation of reviewer "stables," possibly combined with the random selection of reviewers, and increased emphasis on panel review.

e. Blind Reviewing

In "blind reviewing" the name of the proposer is deleted from the proposal before it is provided to reviewers. The principle on which this idea is based is that proposals should be evaluated on the basis of their written content only; it being presupposed that the likelihood of success of the proposed project can be judged without knowing the identity of the proposer.

Blind reviewing is used with some success by a few scientific journals, but as mentioned earlier, a journal article is a finished piece of work, whereas proposed research is not. A few witnesses spoke in favor of blind or half-blind reviewing, but most witnesses were opposed. The Subcommittee's analysis is that blind reviewing of proposals for scientific awards is a procedure with little potential merit. The one known "pro" and the many "cons" are:

PRO

If the blindness of a proposal can be maintained, the reviewer cannot play favorites or otherwise be biased by his knowledge or ignorance of the proposer.

CON

1. Most importantly, the identity of the proposer is a significant factor in determining the likelihood of success of a project. The elimination of knowledge of this factor from the ken of the reviewer is likely to lead to a decrease in the average quality of research performed with the Foundation's assistance.

2. Concealing the identity of the proposer from a reviewer would be difficult in many cases. Proposals frequently contain references to the proposer's past achievements including citations of papers written. Such proposals would have to be rewritten or edited. A description of available experimental facilities or other pertinent information may provide the tipoff.

3. Reviewers may refuse to participate if reviewing is blind. Problems of this sort have arisen in blind reviewing of journal articles.

4. The elimination of the name of the proposer would force the reviewer to rely more heavily on the quality of the proposal itself, a measure largely of linguistic rather than scientific ability. Even those who spoke for blind reviewing preferred to have linguistic facility downplayed.

Raymond Bowers:

> (I)n the appraisal one forms some sense of whether that person has a record that suggests he can do the things he is proposing or the institution has the structure to make it plausible. You are withholding a very important piece of information about the plausibility of getting something done when you don't let me know who and where. (468)

Daniel Drucker:

> There is a further difficulty for the reviewer of a proposal. The merits of a paper are contained in it. They can be judged without regard as to who wrote it. The additional essential question to be answered honestly by the proposal reader is whether the investigator is competent to do the actual research proposed. (622)

Heinz Wilsdorf:

> In fact, it is most likely that many a proposer in rich universities gets very effective help in the preparation of his proposals, . . . (I)t should be made

impossible for proposals from different institutions to already have a built-in advantage or handicap depending on the technical production thereof, including photographs, binders, quality of typing, and so forth . . .

Next, in order to insure objectivity of the review, the proposer should be anonymous. (738)

f. Reviewer Stables and Randomization

Lists of approved potential reviewers would be generated by the Foundation (without any particular proposal in mind) in a way to insure that all people on the lists are competent. It was suggested by one witness that people on the list in a given field might be approved by a professional society in the field. Witnesses appeared to believe that the lists should be published or at least available to the public, though this point was not specifically addressed.

The lists might be utilized in various ways. Most witnesses who discussed lists did so in the context of random selection. Alternatively, Foundation program managers might simply be required to choose from the list.

In random selection, for a given proposal, a large list of reviewers is selected and reviewers are chosen at random from the list to review the particular proposal.

Witness opinion about random selection was mixed but more negative than positive overall.

Some pros and cons are:

PRO

1. Random selection would largely eliminate the possibility of the program manager purposely biasing the review through selecting reviewers whose opinions he can predict.

2. The existence of a public list of potential reviewers might assure the applicant and the public that objective decision-making is taking place.

CON

1. Most importantly, the potential for a review by the most knowledgeable people in a carefully balanced reviewer group would be seriously diminished. It is unlikely that any randomizing procedure, however carefully designed, could result in an overall review of as high quality as could be obtained by purposive selection of reviewers.

2. Administering and auditing random selection would impose an added workload on the Foundation, the proportions of which are likely to be significant.

3. The lists of potential reviewers would be a source of contention. There would be disagreement on the criteria for putting people on the lists or removing them.

William Carey:

I think part of the responsibility of the program manager is to use his head, and in using his head, he has to look at the identities of the peer reviewers. (778)

I think if you blindfold them and compel them to play a randomization game, then you are going to miss an awful lot. You are going to do something to diminish the responsibility of the government employee. And I think that diminished responsibility in government employees is not the way we should be running the government. (788)

Donald Rice:

The idea of a randomized kind of selection procedure is one alternative which does have some merits in building in a measure of objectivity in that selection

process. I think it is only one of a number of things which ought to be considered . . . . (769)

I would also like, at this time, not to be put down as a fan of random selection. I think that subject needs further examination. (788)

HeinzWilsdorf:

I propose that the reviewers be chosen by lot or by some mechanism, and that this would be a random mechanism. (747)

g. Peer Panels

The most cogently supported suggested change in the use of peers to assist in evaluating grant applications at the National Science Foundation is to increase reliance on peer panels.

There is a successful paradigm for the use of peer panels, their use at NIH, described earlier in this report. The strongest arguments for peer panel review at the Foundation were set forth by Philip Handler, former chairman of the National Science Board, who proposed standing panels with rotating membership, viz.:

(1) Such an arrangement avoids the possibility of personal arbitrariness on the part of program managers. . . . the appearance . . . of such behavior is avoided by a formal meeting which leaves behind its minutes, with general rank ordering of the proposals considered, and with a summary of the group's opinion of each application.

(2) It minimizes the possibility of undue influence or bias by individual reviewers in giving preference to grant applicants from particular research-performing institutions or from some school of scientific thought since such individual influences are suppressed or neutralized in the setting of a panel meeting.

(3) In the *ad hoc* mail review system, only the program manager can be influenced by critical information known to and cited by only one of the reviewers, whether that information influence the outcome favorably or unfavorably for the applicant. The staff decision will then seem to be counter to the recommendations of most of the reviewers. But a panel or study section meeting is, in effect, a superlative scientific seminar. I have witnessed many incidents in which a first-rate scientist has revised his previously held judgment of the merits of a particular proposal because of information described by one of the other panel members. In addition, such panel discussion frequently engenders extremely helpful suggestions which can be passed along to the applicant, thereby improving the quality of the work when it is undertaken.

(4) By considering perhaps 40 to 100 applications at a single, several day meeting, the panel can be of considerable additional assistance to the agency. From their discussions, there can emerge a coherent strategic approach to research in a given area of scientific inquiry, which, in effect, becomes agency policy in that regard. By consecutively debating the merits of the proposals before them, the panel gets a better sense of their relative intrinsic merit and thus enables their ordering so as to mount the most effective research effort. (994)

Charles Kidd and John Sherman, both of whom had long experience at NIH, favored panel review.

Charles Kidd:

I feel more confident and relaxed with a system which relies heavily on panels of reviewers . . . I believe frankly that selection of a group of advisors who rotate periodically and who make a collective judgement on applications, in general engenders a sense of confidence among those being judged. The system is one where the selection of reviewers is completely open. Under this system you can have disclosure of who made the decision without any difficulty. (477, 478)

James Powell also spoke strongly in favor of panels, although he did not specify standing panels:

The . . . review process should include both a mail review and a meeting of the review panelists in Washington. (445)

The Foundation already makes fairly extensive use of panels.

Richard Atkinson:

(O)f the applications processed in 1974, 44 percent had ad hoc reviews only, 28 percent had panel reviews only, and 28 percent had both ad hoc and panel reviews. So 56 percent of our proposals will have some form of panel reviews.

Charles Mosher:

(W)hat determines which applicants have only ad hoc review and which have only panel review, and which have both?

Richard Atkinson:

In a certain sense the program officer makes that decision, but by and large it is historical. Certain fields of science have tended to favor panel reviews. Other fields of science have tended to favor ad hoc reviews. (264, 265)

At least one witness believed it inadvisable to increase reliance on panel review:

William Carey:

(P)anels are in effect co-opted as adjunct bodies and incorporated into the decision-making system, rightly or wrongly. If they sit as adjudicators of an array of competing proposals, and rank order them by a balloting procedure, and if their rankings acquire so much weight that the agency officials have in effect delegated responsibility to the panels, then the equations have all been changed. I happen to believe that too much accountability has been handed off by such arrangements. (780, 781)

A second problem with panel review (especially at the Foundation in contrast with NIH) is that in many specialties it may be impossible to assemble a panel knowledgeable enough to expertly evaluate the majority of proposals in the specialty. Yet the number of proposals in the specialty may be too small to warrant the establishment of more than one panel.

The total number of reviewers used by the Foundation would likely be decreased if peer panel review is increased. This might have good effects through allowing more careful attention to the distribution of reviewers or bad effects through the reduction itself.

It is clear that increased reliance on panel review at the Foundation deserves, at the very least, further consideration by the policy-making apparatus of the Foundation.

4. Division of Responsibility

a. General

Present decision-making procedures at the Foundation find an individual staff member in a position of central responsibility in many programs at two key points: the selection of reviewers and the initial decision. Many witnesses suggested changes that would tend to reduce these responsibilities. No witness proposed increasing the responsibilities of individual staff members.

At the point of selection of reviewers, a shift strongly away from the staff is evident if stables of reviewers are instituted. In the case of peer panels the staff would be expected to retain discretion for selection of panel members, although the selection would be much more open to public inspection than is now the case. Another possible change little mentioned at the hearings, would be to require approval of slates of reviewers at higher staff levels before proposals are sent out for review; this practice should be feasible for panel review, but may add a heavy burden if individual peer review is used. The Foundation already requires higher staff approval of reviewers in some programs.

In the case of panel review, the actual initial decision lies more with the peers than if individual peer review is used. Hence, increased reliance on peer panel review would shift responsibility away from the Foundation's staff. More substantive review by higher levels in the Foundation's staff would lessen the concentration of responsibility in the individual staff member making the initial decision. The Foundation is currently creating grant review boards, groups of staff members. These boards will have the effect just mentioned.

Several witnesses emphasized that the Foundation staff must retain the right and ability to go against the recommendations of outside advisors, conceding that such action might be rare. The crucial point is that Federal employees must retain effective control of the process and be able to change it when necessary. No witness contended that the Foundation had lost control of the process.

A certain "conservation of staff responsibility" principle may be seen in witnesses' testimony concerning panels. Those who favored panels (a mechanism limiting staff responsibility) generally also favored having the staff choose the members of the panels. Charles Kidd and Philip Handler are the outstanding examples:

Philip Handler:

> Thus, although the peer reviewers should be heavily relied on for judgments of scientific merit, agency ability to attract outstanding program managers will be diminished if the latter's responsibility for independent scientific judgment is largely removed. Achieving a desirable balance between reliance on outside advice and the exercise of administrative discretion should be an important objective of the peer review management scheme. (996)

b. Missions

Several witnesses agreed that in the support of mission-oriented research it is best to keep basic responsibilities in the staff of an agency. This notion was not challenged. The reasoning is that in mission-oriented research, since there is a specific goal, it may be possible to tell what information is needed to reach the goal, and the responsible staff member should be well-acquainted with which of the information is known and which unknown. Thus the staff member can better judge the key issue of the importance of a proposed bit of research in fulfilling the mission's objective than can extramural experts. This was brought out in the Foundation's testimony concerning its evaluation methods in the Research Applications Directorate, by William Raney concerning the Office of Naval Research, and by others to a lesser extent.

5. Policing the System

To insure that the Foundation's decision-making processes are working properly, it is necessary that information be available about the processes and that someone analyze the information. What the information should be, just what analysis should be undertaken, and who should do it were the subjects of much testimony.

Two loci of information received particular attention: the "grant jackets" and a management information system. Each proposal (other than travel grant or fellowship applications) normally has its own "grant jacket," a file containing at least the proposal, peer reviews of the proposal, and a record of decisions made on the proposal. Witnesses agreed there should be a document (or documents) in the grant jacket outlining the rationale for whatever decisions had been made.

The second locus of information is a Foundation management information system which would retain, among other things, the names of reviewers and proposers, recorded in association with further pertinent information (e.g., institution, proposals reviewed, proposals submitted, etc.). The need for a management information system was particularly evident in questions of the distribution of reviewing. The Foundation has begun the establishment of a management information system.

Witnesses' approaches to the question of what analysis should be undertaken (and to questions of degree of openness, as is discussed further on) revealed a fundamental difference in philosophy among witnesses. One group, the spokesman for which was Rep. John Conlan, believed it best to design decision-making systems defensively, i.e. on the presumption that the proportion of dishonest or unscrupulous people among Foundation program managers and reviewers is high enough to cause severe problems if those people have a significant opportunity to turn the system to their advantage. The second, larger group, the most outspoken member of which was Rep. Charles Mosher, believed that the system should be designed on the presumption that program managers and reviewers are, on the whole, honest and ethical, but that vigilance should be maintained over the system in such a way as to insure that unscrupulous acts are rare. The Subcommittee subscribes to this second viewpoint.

John Conlan:

> I know from studying material provided to me by NSF that this is an "Old Boy's System," where program managers rely on trusted friends in the academic community to review their proposals. These friends recommend their friends as reviewers. . . .
>
> Without any effective management control procedures to insure accountability in this kind of system, it is almost inevitable that some program managers may almost unconsciously become advocates for certain scientists and their projects. . . .
>
> It is an incestuous "buddy system" that frequently stifles new ideas and scientific breakthroughs, while carving up the multimillion dollar Federal research and education pie in a monopoly game of grantsmanship. (5)

Charles Mosher:

> It is my personal belief that whatever mechanism is used to accomplish the job that the peer review system attempts to accomplish, in the long run it all depends on the integrity of the people involved. (169)

William Carey:

> I think you have to trust people. If you hire good people and you want to make them understand what the public ethics are in the management of money, then I think you give them a chance to do it right. (788)

Tom Harkin:

> It goes to the old principle of trust. You have to trust people . . . it seems that because we don't trust people that we have to get more and more police. I don't mean uniformed police, more people to check the checker and somebody else to check the checkers who are checking the checkers because you can't trust them. It seems to me we could have a lot less government in the country today if people trusted people a little more. (241, 242)

The analysis to be undertaken in accordance with general reliance on trust accompanied by vigilance was suggested by several witnesses. It falls in two parts: continued oversight of the broad issues (distribution of funds and reviewers, success ratios, etc.) using information largely contained in the Foundation's management information system, and random audits of the decision processes for individual grants

using information largely contained in the grant jackets. These audits would investigate such matters as ties between program managers and grantees and between reviewers and grantees. Witnesses who discussed decision process audits believed these should be internal to the Foundation and performed by a group not part of the decision-making apparatus for individual grants (and separate from the auditing functions of the General Accounting Office, which should be continued). Oversight functions of Congressional committees are discussed in the next section.

William Carey:

The people at the top of the agencies should not assume that all is well with peer review until they find out differently. I do not favor imposing formidable administrative controls because I believe this would have a smothering effect. A selective, random audit of staff practices regarding peer review is what I have in mind, and I think it would convey the proper message. (781)

Vincent Haneman:

I would like to ask if there is any way to measure invidious relationships between groups of reviewers and groups of awardees?

Now my answer to that question is yes. This is done by an internal audit system that should be developed and in operation by the NSF. I see no reason at this time why this could not be accomplished almost immediately. (620)

Donald Marlowe:

I believe that it is possible to have internal audit systems that continuously monitor the flow of proposals, awards and provides solid data to answer the questions that have plagued the system for years . . . when an audit system is designed, it should be kept separate from the operating line organization . . . I don't want to see all the intellectual effort of the directors of these programs go into the monitoring of the system rather than directing the system . . . I suggest that such an auditing system could probably be done on a sampling basis. . . . (618)

6. Congressional Oversight

The Subcommittee had ample opportunity during the hearings to explore whether Congressional review of individual National Science Foundation grants should be required in addition to Foundation approval before the Foundation's action becomes final. Robert Bauman, the best-known proponent of this idea, appeared as a witness. Many other witnesses and Subcommittee members addressed the issue as well. Opinion was overwhelmingly against Congressional review.

The argument for Congressional review is that the Foundation has apparently been making a large number of grants for research of dubious value and will continue to do so unless Congress checks each proposed grant to ascertain for itself the merit of the proposed research.

Arguments against Congressional review are:

1. The review of individual grants is not the proper way for Congress to exercise its oversight of an agency. Congress should not try to be part of the day-to-day operation of executive agencies, but should review agency performance more broadly, intervening in detail only in particular instances where malfunctioning appears to be serious.

2. Congressional review would tend to make the Foundation less willing to fund innovative ideas.

3. Congressional review would tend to politicize the award decision-making process.

4. Proper Congressional review would entail a great deal of Congressional staff effort and would further lengthen the time it takes applicants to obtain funding and proceed with their research.

James Symington:

> The role of Congress and this Committee is and has been to review the program and budgets of the executive agencies. Necessarily, the emphasis in this process is upon the major objectives of managerial performance and program achievement. In my view, Congress is not at its best when it enters into detailed review or attempts to intervene in the analysis of research projects where scientific opinions differ. (878)

William Carey:

> I would regard the Bauman amendment, . . . as a very serious barrier to the type of evaluation of risk and value in risk-taking, which is part of the discovery process, if it were enacted and carried out, . . . I think the whole bureaucracy would play it so safe and so placidly and cautiously just to stay out of the rain and the thunder and the lightning that I think it would have a decidedly braking effect through indirection. (777)

Charles Mosher:

> Referring to Mr. Bauman's proposal, I would merely say that I think Congressmen would be far more timid and far more conscious and less likely to support innovation, particularly radical innovation, than the scientific community. (285)

Thomas Harkin:

> (P)hilosophers have dreamed for centuries of a country, of a nation, where inquiry, where freedom of thought, inquiry of any nature would not be subject to the political pressures of the monarchy or dictator. I feel whenever inquiry and freedom of thought is placed beyond the realm of the politician, then that country acquires a spiritual strength that makes it, in fact, a beacon of liberty in the world. That is what I want to protect. I don't want to become another Soviet Union or China, where all scientific thought is dictated, where people are channelized into their programs. I want freedom of—whatever nature, social sciences, hard sciences—freedom to inquire and to challenge, the freedom to challenge the most deeply rooted belief that people hold. Only by doing that can people really change and grow.
>
> I think this prior approval would take away that freedom of inquiry. (240)

James Symington:

> I think whatever kind of frying pan we may be in now with respect to oversight might turn into a fire of old boyism if Congress became the court of last resort on all these grants . . . Little by little, it seems to me, a form of congressional courtesy would take over which might even turn into an active club on the NSF to go forward with grants which it may have had some suspicion about. (241)

As it pertains to the Foundation's decision-making system for individual awards, there are several ways in which Congressional oversight should be carried out. Proper execution of oversight responsibilities requires that certain data be available to various arms of Congress.

There was strong disagreement between Rep. John Conlan and Foundation witnesses concerning the willingness of the Foundation to provide information to Congress. The record shows the facts to be as follows:

Non-confidential Information: Unless the Foundation has implicitly or explicitly promised a source that it will keep information confidential, the information will be provided promptly upon reasonable request to any Member of Congress. The record of correspondence between Rep. Conlan and the Foundation contained in the hearings record is ample evidence.

Confidential Information: If the Foundation has promised that information will be kept confidential, it will be made available on request to the General Accounting Office, the House Committee on Science and Technology or its Subcommittee on Science, Research and Technology, and to the Senate Committee on Labor and Public Welfare or its Subcommittee on the National Science Foundation. The Foundation requests that any arm of Congress using confidential information provided by the Foundation take steps to maintain the highest degree of confidentiality of the information compatible with effective oversight. The Foundation has refused, however, to provide confidential information to individual Members of Congress. The Subcommittee believes these arrangements for the treatment of confidential information are suitable and allow for effective oversight of the Foundation while avoiding disruption of the Foundation's decision-making processes.

The kind of confidential information that has heretofore been the principal bone of contention is verbatim peer reviews and the identification of which peers reviewed a given proposal. Rep. Conlan has requested and been denied access to such information. The GAO routinely has access to and uses it. Neither the House Committee on Science and Technology nor its Subcommittee on Science, Research and Technology has requested access.[1]

C. INFORMATION EXCHANGE AND APPEALS

1. Degree of Openness

The most thoroughly discussed issue of the hearings was this: How far can openness of the decision-making process coexist with the effective evaluation of award applications by the National Science Foundation?

There was overwhelming agreement that openness per se is desirable irrespective of its effects on the process and that applications ought to be evaluated effectively. The extent to which these two desiderata are in conflict, and which should be favored in the conflict were hotly debated.

Charles Mosher:

> I am certainly one, Mr. Chairman, who has always believed in openness as the best type of a system in all levels of government. (30)

James Scheuer:

> Recently we have discovered what a cleansing effect openness has. It seems to cure a lot of problems. (579)

One set of arguments concerned the extent to which the comments and identity of peer reviewers should be known. The alternatives fall roughly on a line from most secret to most open as follows: commentary accompanies the viewpoints.

1. Applicants should know nothing about who reviewers were or what they said.

No one ascribed to this extreme position.

2. Applicants should receive paraphrased reviewer comments on request but should not know the identity of reviewers.

> This represented Foundation policy for many years until it was changed in June 1975 by the National Science Board. The new policy is given by item (3). It took effect January 1, 1976.

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[1] Beginning in 1976, the subcommittee has examined certain confidential documents of the National Science Foundation, overtaking publication of this report.

3. Applicants should receive verbatim reviewer comments on request but should not know the identity of reviewers.

This has been the Foundation's policy since January 1, 1976. Witnesses who agreed that this option or the preceding one is best included: Raymond Bowers, William Carey, Daniel Drucker, Vincent Haneman, and Donald Marlowe. Witnesses whose opinion lay between this option and the next one included: Philip Morrison, James Powell, and Donald Rice.

4. Applicants should receive signed verbatim peer reviews on request.

Rep. John Conlan and Heinz Wilsdorf believed this would be best.

5. Applicants and the public at large should have access to signed verbatim peer reviews.

No one claimed this would be a good policy.

The National Science Board has been deliberating the confidentiality issue. The arguments it has considered encompass all the major arguments made at the peer review hearings and were elegantly summarized by Donald Rice, viz:

> Mr. Chairman, there is, as you are well aware, probably no more sensitive issue in the award decisionmaking process than the question of confidentiality. I can say that with considerable conviction because the task force spent nearly all of its time examining the pros and cons of that one subissue alone at our meeting in June. I would like to list for you some of the major arguments for and against confidentiality.
>
> Those who favor confidentiality in some degree argue one or more of the following:
>
> (1) Reviewers will be more candid on all aspects of the proposal, and the qualifications of the proposer to accomplish the work, if their identity and/or verbatim comments are kept confidential and not passed on to the proposer. Thus, confidentiality, in this view, contributes to the quality of reviews.
>
> (2) Providing names of peer reviewers to principal investigators is likely to encourage personality clashes between the proposer and the reviewer, leading to unnecessary ill will and hard feelings among all parties concerned.
>
> (3) Program managers might have to take on the role of arbitrators between proposers and reviewers, and would also find themselves spending more and more of their time defending their decisions orally and in writing. This would add measurably to their workload, and make it more difficult to come to the decisions they have to reach.
>
> (4) Many potential reviewers would refuse to participate in a system that required them to be identified with their comments to the authors of the proposals they have reviewed.
>
> (5) Unless their identity was protected, reviewers would be reluctant to comment critically on proposals by others who could adversely affect the career path of the reviewers.
>
> (6) The identification of reviewers would increase the opportunity for political pressures to intrude on the system. I understand, Mr. Chairman, that this particular problem has already been discussed, as have others, at these hearings.
>
> Those favoring an open system argue one or more of the following:
>
> (1) Qualified reviewers can be relied upon to be candid and straightforward in their evaluation of a proposal, regardless of whether the system is open or closed. Reviewers who are not willing to defend their positions in an open system ought not to be reviewing Federal grant proposals in any case.
>
> (2) Openness would result in more responsible and objective reviews. Superficial or personality-based comments would diminish, and the result would be a more focused and effective evaluation.
>
> (3) Qualified scientists will continue to participate in the interest of furthering the best quality science.
>
> (4) Confidentiality makes the system unnecessarily difficult to defend from charges of internal bias, old-boy network practices, favoritism, or other criticisms. That is, an open system can better demonstrate its impartiality and effectiveness.

(5) An open system would increase the workload of program officers in some ways and reduce it in others. In any event, staffing levels can be adjusted to the new workload.

(6) Openness means change and change may cause some problems initially; but, in the long run, the system will recalibrate and stronger reviews will result. The new system will stand public scrutiny, and science will achieve a higher level of credibility. (767, 768)

These arguments are directed primarily towards making a decision between position 3 and position 4 from the list of five viewpoints. Witnesses generally believed that the Foundation's new policy, position 3, will be an improvement over the old one, position 2, but the kind of information presented in support of this belief and in support of the arguments summarized above was largely anecdotal, or personal opinion, or a small opinion survey.

The type of information presented concerning two critical questions is summarized below.

1. What will happen to the quality of reviews if signed verbatim reviews are provided to applicants (and, possibly, to the public)?

Those who said that quality would either stay the same or improve cited only their own personal opinion.

Those who said that quality would deteriorate cited their own opinions and:

(a) Vincent Haneman surveyed 172 engineers; 76 responded. Dr. Haneman reported that when asked "if it were the will of Congress that public identity of the reviewer be published along with his review, . . . (would) more candid, honest evaluations . . . result from those who did volunteer?" Eight said yes and 64 indicated less candid, less honest evaluations.

(b) The analogy was drawn between peer reviews and personal recommendations. One witness pointed out that on his campus the contents of a student's personnel file were available for perusal by the student. This had resulted in student evaluations by professors that were exclusively positive.

(2) How many people will refuse to be reviewers if signed verbatim reviews are provided to applicants (and, possibly, to the public)?

Those who said the number would be comparatively small cited only their own opinions.

Those who said the number would be relatively large cited their own opinions and:

(a) The witness who pointed out the analogy to personal recommendations said several professors had refused to write evaluations of students under the open system.

(b) Of Vincent Haneman's survey respondents, when asked "would the faculty still be available to provide this service?" Under the conditions described earlier, 27 said yes and 46 said no.

Additionally, it is worth noting that in current practice the NIH study section system and the Foundation ad hoc reviewing system share the principle that reviewers' names should be separated from their opinions in material provided to applicants, in that the Foundation will be providing verbatim comments but withholding reviewers' names, whereas NIH makes names available but maintains separation by paraphrasing comments. In his suggestions for review at the Foundation, James Powell implied that if individual verbatim reviews were provided to applicants, reviewer names should be withheld, but

if panels are employed, names should be provided. There is a degree of realism observable in current practice that should be kept in mind, which is that it is impossible to keep secret the names of members of a standing committee who travel to Washington several times annually—so to be equitable they should be published so that the entire community will be informed, not just a favored part of it. On the other hand, it is a fairly simple matter to maintain the names of mail reviewers in confidentiality.

As the following resolution shows, the National Science Board has decided to make available the names of peer reviewers in an aggregated form. All witnesses who mentioned it felt this was a step in the right direction, but several felt that the reviewer list should be broken down to identify the reviewers in particular Foundation programs. The list of reviewers used by the Foundation in 1974 has been prepared by the Foundation and printed by the Subcommittee. The level of aggregation of future lists is a subject of continuing debate. One contribution of the list will be to allow for the recognition of those scientists who have contributed to the advance of science through reviewing applications submitted to the Foundation.

RESOLUTION ADOPTED BY THE NATIONAL SCIENCE BOARD AT ITS 174TH MEETING ON JUNE 20, 1975, ON PEER REVIEW INFORMATION

The National Science Board has examined the use of peer review in the National Science Foundation decision process on grant awards and declinations. The Board intends the peer review process to aid the effective evaluation of proposals with the fairest possible treatment of each individual proposal and the broadest possible participation of qualified scientists and other appropriate persons. The Board intends that the review process be conducted with as much openness and information to proposers as possible consistent with effective administration of the decision process. To these ends the National Science Board *Resolved* that:

1. The Foundation will publish annually a list of all reviewers used by each Division;
2. Program officers should seek broadly representative participation of qualified individuals as reviewers;
3. Verbatim copies of reviews requested by the Foundation after January 1, 1976, not including the identity of the reviewer, will be made available to the principal investigator/project director upon request. The question of including the identity of the reviewer will be considered further by the National Science Board;
4. The Foundation, upon request, will inform the principal investigator/project director of the reasons for its decision on the proposal.

All reviews requested prior to January 1, 1976, will continue to be governed by earlier policies since those reviews will have been solicited with a commitment on the part of the National Science Foundation to the confidentiality established by that earlier policy.

The Board believes this new policy will serve to improve the information exchange with the scientific community and allow it to better understand the reasons behind National Science Foundation decisions.

2. Feedback to Applicants

The question of what information should be provided to applicants is obviously intertwined with the confidentiality issue just discussed. Excluding the matters of reviewers' names and verbatim comments, however, there was general agreement among witnesses who addressed feedback that proposers should have the right to know the rationale behind the decisions taken on their applications, and should be able to get it in writing. Moreover, proposers should be informed of their right to feedback as a matter of course; it was not clear from the testimony whether the Foundation has adequately notified applicants in the past concerning what information they may have on request.

3. Appeals

Neither the Foundation nor NIH has a formal procedure whereby an applicant whose proposal has been rejected can have the same proposal reconsidered. A rejected applicant is expected to revise and resubmit the proposal if a new review is desired. Instances of revision and resubmission are common at the Foundation. In the comparatively rare instances of allegations from proposers that the Foundation should reconsider a proposal, the Foundation acts in an ad hoc fashion, normally at least checking that appropriate procedures were used in the evaluation of the proposal.

The consensus of witnesses who addressed the issue of appeals was that the Foundation should have an established policy allowing some form of appeal by a rejected applicant, but that the policy should not make an appeal so simple that applicants would overload the system with appeals.

A variety of differing appeal procedures were suggested by: (1) Carlton Hazlewood, Gilbert Ling, and Freeman Cope, (2) Heinz Wilsdorf, and (3) Rustum Roy, but none was widely endorsed. None of those suggested has immediate and conspicuous attractiveness to the Subcommittee. Others who spoke in favor of appeals (William Carey, Donald Marlowe, James Powell) made no suggestions for procedures.

Arguments for appeals are:

1. The Foundation is not perfect; it undoubtedly makes poor decisions on occasion. To be fair there should be a way for an aggrieved applicant who has been rejected in a poor decision to have a new hearing.

2. If peer review does tend to reject innovative proposals, since innovation is essential to the progress of science, a procedure is needed to check peer review and insure that important innovations are supported.

Arguments against appeals are:

1. It is recognized that many proposals of sufficiently high quality to have been funded in former years are currently being rejected by the Foundation because of funding limitations. If an appeals procedure is available it will be used by so many people that an inordinate proportion of the Foundation's efforts will be devoted to handling appeals.

2. Formal appeal procedures will introduce adversary relationships into the scientific community that have heretofore, fortunately been missing. If there are frequent or conspicuous confrontations—between reviewers and applicants, in particular—the peer review system will be jeopardized.

D. DISTRIBUTION OF FUNDS

1. Geographical Distribution

Discussions of the issue of distribution of funds suffer from the fact that although the law concerning the Foundation enjoins the Foundation to "avoid undue concentration of such research and education," neither the Foundation nor Congress has attempted to define "undue." Judgements of the Foundation's performance are consequently very subjective and open to disagreement.

Of the various distribution issues, geographical distribution was the most thoroughly discussed. The Foundation produced two reports dealing with distribution for the hearings, "An Analysis of the Geographical Distribution of NSF Awards as Compared with Other Selected Indicators" and "NSF Management Statistics." Both reported data for Fiscal Year 1974 and are included in the record with the testimony of Richard Atkinson. A copy of the summary data sheet from the "Geographical Distribution" report follows. The testimony of Richard Atkinson dealt explicitly with geographical distribution, and several additional graphs were presented depicting the distribution of Foundation funds. Only one other witness, Doris Wilsdorf, presented geographical distribution data.

Some observations concering the data provided by the Foundation follow. The Subcommittee believes these observations show that on a Foundation-wide basis the distribution of funds is at least not grossly unfair. The other information available to the Subcommittee is not in dissonance with this conclusion. The aggregation of data over all Foundation programs, however, masks the distribution of funding in any given program, and it cannot be concluded from the available information that the distribution in any program is fair or reasonable by some measure. On the other hand, neither was any data presented to the subcommittee which demonstrated unfair distribution of funds in any Foundation program, although Prof. Wilsdorf purported that her data indicated "That geographical concentration of funding rather than dispersal of funding has taken place."

1. The success ratios of the 51 states (including the District of Columbia), vary from a low of 30 percent (South Carolina) to a high of 60 percent (District of Columbia). The success ratio is the proportion of proposals from the state that are funded in some amount by the Foundation. The best success ratio is thus not excessively high and only twice as high as the worst success ratio, which is not excessively low.

2. Excluding success ratios, the rankings on the summary data sheet of states by ten other indicators of state size and Foundation awards show that most states are ranked similarly by all indicators. Forty states have at least nine of the ten indicators lying in some 11-point nterval. Connecticut, for instance, has rankings of 17, 20, 19, 24, 18, 22, 25, 22, 22, and 16, all ten of which fall in the 9-point interval from 16 to 25.

3. The dollar amounts of Foundation awards per science or engineering doctorate holder on the other hand vary widely. Thirty-two states received between $1,000 and $3,000 per such doctorate. Nine received less, to a minimum of $500 (Idaho), and ten received more, to a maximum of $14,000 (West Virginia). Most of these nine are scientifically unique in certain respects (Alaska, Hawaii, and three states of modest population with National Centers supported by the Foundation, for example).

The variation of Foundation funding with respect to population is similarly wide.

The Foundation's policy has been that in cases where applications are of substantially equal scientific merit, consideration should be given to geographical distribution in the decision of which applications will be funded. This policy has had the advantage of avoiding the "apples and oranges" problem of weighing geography against merit; merit is given pr macy, and geography serves to help make fine distinctions.

All witnesses who addressed the question of how geography should be factored into the Foundation's disbursement of funds agreed that peer review procedures should not be expected to encompass geographical considerations. Several of those witnesses went further and said that if Congress finds the distribution of Foundation funds currently lacking in some respects, Congress should establish special programs to redress the imbalances rather than attempting to adjust decision-making procedures for present programs to effect a redistribution. Charles Kidd explored this matter in some detail.

Raymond Bowers:

> The peer review process is largely designed to maintain quality. But quality of scientific work is not the only factor that should be considered in the allocation of Federal moneys. Relevance to national goals and considerations of geographical distribution are proper concerns. . . . However, I would not look to the peer review system of itself to be the principal administrative device for achieving these other purposes. They require the design of special programs and special procedures. (466)

Charles Kidd:

> The peer review system carries out basic goals set by Congress and in greater detail by the Federal agencies. Those who deplore concentration of funds and concentration on support of science should attack the basic policies and programs themselves and not the peer review system. (475)

In the past Congressional concern for the nationwide strengthening of science was such that there were special programs devoted to that purpose. These have now been largely shut down. Within the Subcommittee there was substantial disagreement concerning the emphasis that should be placed on geographical distribution.

Rep. James Scheuer said the Foundation should use Federal funds to support excellence, wherever and in whatever concentration it may be found. Rep. Walter Flowers, contrariwise, said he thought the Foundation was not heeding the provision to "avoid undue concentration" and said there was a great deal of room for improvement.

It must be observed, moreover, that the Foundation, while the main supporter of many fields of basic science, provides only a small fraction of the total support for scientific research and education in the United States. If there is or is to be a national policy concerning the geographical distribution of funds for science, it will have to encompass at least those agencies which provide the bulk of the funds in order to be effective. Requiring even geographical distribution of the Foundation funds only will not achieve the result which might be desired of assuring geographically broad performance of research.

The effect of multiple funding sources on the distribution of funds is intensified when a single specialty is considered. To examine Foundation support of atomic physics without concurrently investigating ERDA support, for example, would result in a thoroughly distorted evaluation of whether the levels of support for the subdisciplines of atomic physics by the Foundation are reasonable.

SUMMARY DATA SHEET

GEOGRAPHICAL DISTRIBUTION OF FY 1974 AWARDS, DOLLARS AND OTHER SELECTED INDICATORS

STATE	NSF AWARDS						TOTAL ACTIONS			SUCCESS RATIO		TOTAL POPULATION			DOCTORAL SCIENTISTS AND ENGINEERS IN LABOR FORCE				ENROLLMENT IN INSTITUTIONS OF HIGHER EDUCATION			SCIENCE AND ENGINEERING GRADUATE STUDENTS			PH.D. SCI. AND ENG. EMPLOYED IN UNI. AND COLL.			PH.D.'S AWARDED IN SCIENCE AND ENGINEERING			NSF ADVISORY GROUP MEMBERS		
	NUMBER	PERCENT	RANK	$ IN MILLIONS	PERCENT	RANK	NUMBER	PERCENT	RANK	PERCENT	RANK	NUMBER IN THOUSANDS	PERCENT	RANK	NUMBER	PERCENT	RANK	% OF TOTAL POPULATION	NUMBER IN THOUSANDS	PERCENT	RANK	NUMBER	PERCENT	RANK	NUMBER	PERCENT	RANK	NUMBER	PERCENT	RANK	NUMBER	PERCENT	RANK
ALABAMA	59	.6	33	2.3	.4	34	176	.8	32	34	50	3,539	1.7	21	2,255	1.0	29	.06	118.8	1.3	27	1,353	.6	36	1,436	1.1	28	133	.7	32	6	.9	27
ALASKA	51	.5	36	3.1	.5	31	89	.4	40	57	4	330	.2	51	348	.2	51	.11	13.7	.1	51	255	.1	51	193	.2	51	12	.1	50	1	.2	48
ARIZONA	113	1.1	25	15.7	2.6	10	216	1.0	30	52	11	2,058	1.0	32	2,216	1.0	30	.11	123.7	1.3	24	3,487	1.6	21	1,407	1.1	29	230	1.2	29	5	.8	32
ARKANSAS	27	.3	45	.6	.1	48	80	.4	43	34	49	2,037	1.0	33	766	.3	43	.04	53.9	.6	37	733	.3	41	744	.6	39	40	.2	45	3	.5	38
CALIFORNIA	1,412	14.0	1	94.6	16.6	1	2,433	11.7	1	58	2	20,601	9.8	1	26,159	11.4	1	.13	1,375.0	14.9	1	22,645	10.5	2	11,021	8.8	2	2,127	11.5	1	79	11.9	1
COLORADO	237	2.3	14	34.5	6.1	4	514	2.5	12	46	25	2,437	1.2	28	4,266	1.9	17	.18	129.2	1.4	23	4,283	2.0	13	2,260	1.8	21	338	1.8	18	11	1.7	18
CONNECTICUT	205	2.0	17	8.0	1.4	20	377	1.8	19	54	9	3,076	1.5	24	4,245	1.9	18	.14	131.0	1.4	22	3,083	1.4	25	2,242	1.8	22	274	1.5	22	13	2.0	16
DELAWARE	38	.4	41	2.2	.4	35	81	.4	41	47	21	576	.3	47	2,714	1.2	24	.47	27.8	.3	47	782	.4	40	369	.3	48	60	.3	41	2	.3	42
DISTRICT OF COLUMBIA	241	2.4	12	20.0	3.5	7	401	1.9	17	60	1	746	.4	43	6,762	3.0	11	.91	80.5	.9	33	4,163	1.9	15	1,207	1.0	32	261	1.4	24	47	7.1	3
FLORIDA	236	2.3	15	13.1	2.3	13	530	2.6	11	45	33	7,678	3.7	8	4,871	2.1	14	.06	260.1	2.8	9	4,691	2.2	12	3,290	2.6	12	342	1.9	17	12	1.8	17
GEORGIA	163	1.6	20	5.5	1.0	27	386	1.9	18	42	38	4,786	2.3	14	3,465	1.5	23	.07	141.2	1.5	20	3,370	1.6	23	2,598	2.1	18	238	1.3	28	6	.9	27
HAWAII	70	.7	32	4.0	.7	29	122	.6	36	58	3	832	.4	40	1,133	.5	38	.14	42.5	.5	40	1,482	.7	34	664	.5	40	71	.4	38	2	.3	42
IDAHO	22	.2	49	.4	.1	51	46	.2	50	48	19	770	.4	42	837	.4	41	.11	35.1	.4	41	677	.3	42	454	.4	44	30	.2	47	5	.8	32
ILLINOIS	533	5.3	4	28.5	5.0	5	1,046	5.0	5	51	13	11,236	5.4	5	11,013	4.8	4	.10	486.4	5.3	4	10,828	5.0	5	6,768	5.0	5	1,229	6.7	3	27	4.1	5
INDIANA	273	2.7	9	12.7	2.2	14	537	2.6	10	51	14	5,316	2.5	11	5,189	2.3	13	.10	201.4	2.2	12	5,847	2.7	10	3,299	2.6	11	680	3.7	9	16	2.4	14
IOWA	102	1.0	29	3.9	.7	30	227	1.1	27	45	31	2,904	1.4	25	2,351	1.0	28	.08	109.5	1.2	28	3,329	1.5	24	2,092	1.7	23	405	2.2	12	7	1.1	25
KANSAS	86	.9	30	2.2	.4	36	230	1.1	26	37	44	2,279	1.1	30	1,988	.9	34	.09	107.9	1.2	30	3,042	1.4	26	1,688	1.3	25	268	1.5	23	6	.9	27
KENTUCKY	59	.6	33	1.3	.2	43	155	.7	34	38	42	3,342	1.6	23	2,158	.9	31	.06	108.2	1.2	29	1,403	.6	35	1,553	1.2	26	113	.6	33	3	.5	38
LOUISIANA	104	1.0	28	2.5	.4	33	254	1.2	25	41	39	3,764	1.8	20	2,709	1.2	25	.07	134.4	1.5	21	2,501	1.2	29	2,047	1.6	24	240	1.3	26	10	1.5	20
MAINE	33	.3	43	.7	.1	47	72	.3	44	46	27	1,028	.5	38	756	.3	44	.07	34.6	.4	42	422	.2	49	552	.4	41	12	.1	51	4	.6	34
MARYLAND	225	2.2	13	11.3	2.0	16	450	2.2	14	50	15	4,070	1.9	18	7,773	3.4	10	.19	168.0	1.8	17	4,140	1.9	16	2,873	2.3	14	316	1.7	19	22	3.3	10
MASSACHUSETTS	752	7.5	3	55.5	9.8	3	1,320	6.4	3	57	5	5,818	2.8	10	9,989	4.4	7	.17	321.9	3.5	8	12,263	5.6	3	6,346	5.1	4	1,102	6.0	4	43	6.5	4
MICHIGAN	367	3.6	7	15.2	2.7	11	807	3.9	7	46	29	9,044	4.3	7	8,165	3.6	9	.09	406.7	4.4	6	9,678	4.5	8	4,549	3.6	8	905	4.9	6	27	4.1	5
MINNESOTA	130	1.3	23	5.2	.9	28	277	1.3	23	47	22	3,897	1.9	19	4,079	1.8	20	.10	158.0	1.7	18	3,933	1.8	18	2,573	2.1	19	362	2.0	16	6	.9	27
MISSISSIPPI	45	.4	38	2.1	.4	37	119	.6	37	38	43	2,281	1.1	29	1,090	.5	40	.05	80.3	.9	34	1,258	.6	37	914	.7	35	100	.5	34	4	.6	34
MISSOURI	165	1.6	19	6.4	1.1	24	413	2.0	16	40	40	4,757	2.3	15	4,181	1.8	19	.09	188.9	2.1	15	4,237	1.9	14	2,810	2.2	15	382	2.1	14	15	2.3	15
MONTANA	33	.3	43	1.3	.2	44	69	.3	46	48	20	721	.3	44	714	.3	45	.10	28.2	.3	46	629	.3	44	529	.4	43	56	.3	42	2	.3	42
NEBRASKA	40	.4	40	1.6	.3	39	107	.5	38	37	45	1,542	.7	35	1,232	.5	36	.08	66.1	.7	35	1,087	.5	38	925	.7	34	95	.5	35	—	—	—
NEVADA	22	.2	49	.8	.1	46	48	.2	49	46	26	548	.3	48	412	.2	50	.08	17.3	.2	50	383	.2	50	351	.3	49	16	.1	49	4	.6	34
NEW HAMPSHIRE	47	.5	37	1.5	.3	40	101	.5	39	47	23	791	.4	41	807	.4	42	.10	30.2	.3	43	625	.3	45	544	.4	42	54	.3	44	3	.5	38
NEW JERSEY	256	2.5	10	11.8	2.1	15	456	2.2	13	56	7	7,361	3.5	9	9,931	4.3	8	.13	240.9	2.6	10	6,566	3.0	9	3,007	2.4	13	364	2.0	15	23	3.5	8
NEW MEXICO	57	.6	35	1.8	.3	38	159	.8	33	36	47	1,106	.5	37	2,593	1.1	26	.23	48.5	.5	39	1,525	.7	33	751	.6	38	94	.5	36	9	1.4	22
NEW YORK	1056	10.5	2	56.1	9.9	2	2,200	10.6	2	48	18	18,265	8.7	2	23,641	10.4	2	.13	850.5	9.2	2	26,754	12.3	1	12,947	10.3	1	1,877	10.2	2	69	10.4	2
NORTH CAROLINA	171	1.7	18	6.3	1.1	25	373	1.8	21	46	28	5,273	2.5	12	4,727	2.1	15	.09	198.5	2.2	13	4,018	1.8	17	3,462	2.6	10	473	2.6	11	21	3.2	11
NORTH DAKOTA	25	.2	47	.9	.2	45	59	.3	47	42	37	640	.3	46	580	.3	47	.09	29.8	.3	44	459	.2	48	401	.3	47	68	.4	39	2	.3	42
OHIO	324	3.2	8	10.5	1.8	17	761	3.7	8	43	36	10,731	5.1	6	10,067	4.4	6	.09	390.3	4.2	7	10,324	4.7	7	4,915	3.9	7	704	3.8	8	11	1.7	18
OKLAHOMA	79	.8	31	2.7	.5	32	220	1.1	29	36	46	2,663	1.3	27	2,154	.9	32	.08	122.2	1.3	26	3,680	1.7	19	1,256	1.0	30	247	1.3	25	3	.5	38
OREGON	160	1.6	22	7.7	1.4	21	292	1.4	22	55	8	2,225	1.1	31	2,354	1.0	27	.11	123.2	1.3	25	2,705	1.2	28	1,532	1.2	27	315	1.7	20	10	1.5	20
PENNSYLVANIA	508	5.0	5	23.2	4.1	6	1,127	5.4	4	45	30	11,902	5.7	3	12,163	5.3	3	.10	429.7	4.7	5	10,459	4.8	6	6,773	5.4	3	936	5.1	5	23	3.5	8
RHODE ISLAND	128	1.3	24	6.6	1.2	23	227	1.1	27	56	6	973	.5	39	1,213	.5	37	.12	50.0	.5	38	1,563	.7	31	868	.7	36	149	.8	31	4	.6	34
SOUTH CAROLINA	42	.4	39	1.3	.2	42	140	.8	35	30	51	2,726	1.3	26	1,724	.8	35	.06	93.8	1.0	31	1,558	.7	32	1,248	1.0	31	82	.4	37	6	.9	27
SOUTH DAKOTA	25	.2	47	.5	.1	49	72	.3	44	35	48	685	.3	45	466	.2	48	.07	28.9	.3	45	647	.3	43	435	.3	46	34	.2	46	2	.3	42
TENNESSEE	109	1.1	27	7.6	1.3	22	274	1.3	24	40	41	4,126	2.0	17	3,706	1.6	22	.09	147.3	1.6	19	3,371	1.6	22	2,362	1.9	20	289	1.6	21	9	1.4	22
TEXAS	416	4.1	6	16.3	2.9	9	930	4.5	6	45	32	11,794	5.6	4	10,452	4.6	5	.09	487.6	5.3	3	10,915	5.0	4	6,178	4.9	6	811	4.4	7	26	3.9	7
UTAH	111	1.1	26	6.0	1.1	26	212	1.0	31	52	10	1,157	.6	36	2,147	.9	33	.19	82.5	.9	32	2,277	1.0	30	1,120	.9	33	203	1.1	30	7	1.1	25
VERMONT	20	.2	51	.4	.1	50	40	.2	51	50	16	464	.2	49	602	.3	46	.13	25.7	.3	48	509	.2	47	454	.4	44	24	.1	48	1	.2	48
VIRGINIA	163	1.6	20	8.9	1.6	19	375	1.8	20	44	34	4,811	2.3	13	5,589	2.4	12	.12	176.5	1.9	16	2,981	1.4	27	2,674	2.1	16	238	1.3	27	19	2.9	12
WASHINGTON	232	2.3	16	17.7	3.1	8	447	2.2	15	52	12	3,429	1.6	22	3,897	1.7	21	.11	193.1	2.1	14	3,498	1.6	20	2,645	2.1	17	384	2.1	13	17	2.6	14
WEST VIRGINIA	35	.3	42	15.1	2.7	12	81	.4	41	43	35	1,794	.9	34	1,091	.5	39	.06	63.6	.7	36	910	.4	39	795	.6	37	63	.3	40	2	.3	42
WISCONSIN	256	2.5	10	9.8	1.7	18	551	2.7	9	47	24	4,569	2.3	16	4,446	1.9	16	.10	217.8	2.4	11	5,321	2.4	11	3,529	2.8	9	540	2.9	10	8	1.2	24
WYOMING	27	.3	45	1.3	.2	41	55	.3	48	49	17	353	.2	50	449	.2	49	.13	17.7	.2	49	555	.3	46	321	.3	50	54	.3	43	1	.2	42
TOTAL	10,090	100	-	569.1	100	-	20,734	100	-	-	-	209,851	100	-	228,839	100	-	-	9,198.6	100	-	217,399	100	-	125,438	100	-	18,440	100	-	664	100	-

NOTE: DETAIL MAY NOT ADD TO TOTALS DUE TO ROUNDING

2. Institutional Distribution

The distribution of Foundation funds among academic, profit, non-profit, government, and other institutions was not addressed to any significant degree in the peer review hearings (one letter in the record broaches the subject of the funding of for-profit institutions). This is a subject that may deserve further attention at another time.

The preponderance of Foundation funds (about 77% in Fiscal Year 1974) is awarded to academic institutions, however, and there was some discussion of whether the division of Foundation funds among various types of academic institutions is equitable. James Powell argued strongly that basic research awards are too often denied to proposers from colleges (without graduate departments). The statistics show that only about one percent of the total Foundation funds directed to academic institutions go to private, bachelors degree only institutions.

It has been frequently alleged in the past that peer review systems fail to support good scientists at lesser institutions. Two arguments why this may be true are: (a) peer reviewers are less likely to personally know scientists at lesser institutions, and (b) the peer reviewers' perceptions of individual quality may be colored by perceptions of institutional quality—in other words the institution rubs off on the individual. If these two effects are indeed strong, then it may be that the Foundation is getting less for its money than it would if colleges and less prestigious universities were more heavily supported. Foundation witnesses claimed, to the contrary, that scientists in minor institutions would receive at least an even break.

But, there are good reasons why the Foundation should fund less research at colleges and less prestigious universities, and it is extremely difficult not to confound the effects of the good reasons below with those of the bad ones above.

Good reasons: (a) the better research scientists tend to congregate in the better universities, as mentioned earlier; (b) well-to-do universities frequently have experimental facilities and apparatus not found at other institutions; the proposer from the better equipped institution is more likely to succeed in the experiment and, therefore, has a justified edge on the competition; (c) teaching loads at colleges (commonly 12 class hours per week) allow the college professor much less time for research than the university professor with a much lighter teaching load (commonly 6 or 9 class hours per week); (d) at universities, graduate students are available to do much of the routine research work; this provides training for future practicing scientists; if the same research were performed at colleges it may be difficult to find assistance of the same caliber, and the training effects might be dissipated on persons not planning scientific careers.

The last argument may be turned around with some cogency: undergraduates are more enthusiastic, and, if they are the future graduate students, will not dissipate the training. Moreover, the type of baccalaureate-granting institution whose undergraduate students are most likely to go on to earn a doctorate is known to be the good private college.

3. Young Scientists

Those witnesses who mentioned age agreed that it is vital to support the best members of each new generation of scientists. Younger scientists are potentially liable to be at a disadvantage because they have little or no past record by which the quality of their future performance may be estimated. Foundation witnesses said that this would be taken into account by the system; younger investigators would be given a chance to prove themselves. No witness claimed that younger investigators have been underfunded, although Carlton Hazlewood said he had heard complaints about peer review from younger scientists. However, no data whatsoever were presented to the Subcommittee showing how younger investigators have actually fared in recent years.

Guyford Stever:

NSF is increasingly concerned with the entry of younger scientists into Foundation support competition. (141)

Richard Atkinson:

The process is anything but biased in favor of better-known investigators, in fact it may be biased in favor of persons who first appear before the review process. (281)

William Carey:

(We) have very little information that will tell us whether peer review has had good or adverse effects upon the chances of younger scientists to get on with their pioneering . . . I am suggesting that it would be a good thing if peer review could be made into a lively process for discovering and encouraging young talent in science as an explicit function. The NSF seems confident that this is going on. I will only say that it needs to be demonstrated, not merely asserted. (779)

The current employment crisis in science introduces a new difficulty into the support of younger scientists. In many fields of science the size of the national faculty grew rapidly during the 1950's and 1960's but has ceased growing in the seventies. This means that each year there are few positions to fill with new PhD's—especially at the best institutions where, it has been observed, a higher proportion of the faculty is tenured than in other institutions. At the same time, large numbers of new doctorates are being awarded by the nation's universities. The result is that many very competent new PhD's will not be employed by the best institutions. Whereas in the past a very significant proportion of the best young scientists could be found at the most prestigious institutions, the proportion will likely be relatively small in the future. The Foundation may find it necessary to take special steps to insure the rest of the good younger scientists have the opportunity to do research.

E. OTHER

1. National Science Foundation Programs

Three specific Foundation programs were addressed by different sets of witnesses: materials research (Doris Wilsdorf), engineering (Donald Marlowe and Daniel Drucker), and biochemistry (Carlton Hazlewood, Freeman Cope, and Gilbert Ling).

Donald Marlowe and Daniel Drucker proposed that funding of engineering research by the Foundation is inadequate. The Subcommittee has not attempted to analyze this contention in the present

report. As mentioned at the outset, the hearings did not bear on the issue of priority setting among scientific fields and purposes. This is an area of such magnitude and importance it needs and deserves separate, thorough investigation. If the Subcommittee, or another body, does investigate Foundation priority setting at some later date, it would be appropriate to include the issue of support of engineering.

Doctors Hazlewood, Cope, and Ling used a biochemical theory issue to stress the need for a better method of insuring that innovative research is funded. This need has been dealt with in earlier sections of this report concerning innovative research and appeals. The Subcommittee does not choose, however, to attempt to judge the scientific issue involved because the theory in question has been funded by another agency (NIH) and because Subcommittee members believe such judgement lies outside their competence. For the latter reason the Subcommittee has also not attempted to judge the scientific performance of those Foundation staff members concerned with this matter.

The materials research testimony of Doris Wilsdorf has received wide attention since the peer review hearings. Professor Wilsdorf maintained that her survey and analysis of funding by the Foundation's Metallurgy and Materials Section showed that certain university departments were being discriminated against by the Section in such a way that some of the best researchers in the field were being underfunded by the Section. Her methodology relied heavily on citation analysis. Because Doris Wilsdorf's testimony was quite technical, the Subcommittee had it analyzed by the Science Policy Division of the Congressional Research Service. About twenty members of the metallurgy and materials scientific community have written to the Subcommittee concerning the testimony. The Research Service analysis and eight of the letters are included in Appendix II of the hearings record. The analysis and all correspondents are unanimous in their judgement that the methodology of the testimony is faulty. The primary objection is that citation analysis standing alone is inadequate to produce a true measure of the ability of a scientist. A second objection is that, to be meaningful, an analysis of metallurgy and materials funding patterns must encompass all agencies providing support, not only the Foundation. Additionally, many issues concerning technical aspects of the evidence presented by Professor Wilsdorf have been raised. All correspondents who mentioned the Foundation staff said they believe the staff is competent and unbiased. It was not clear, however, whether the Foundation had adequately filled requests by the principal witness for information.

2. Overlap of Research

The National Science Foundation is not, of course, the only Federal agency which supports basic research. There are scientific fields supported by the Foundation and by one or more other agencies. It is inevitable that there will be some projects funded by the Foundation which might equally well be supported by other agencies. Indeed, the Foundation jointly funds quite a number of projects with other agencies. The question to be addressed is, to what extent is overlap of Foundation program areas with other agency program areas desirable.

One witness, Rep. Robert Bauman, felt that such overlaps lead to the Foundation "duplicating the work of other agencies" and should be

eliminated insofar as possible. Other witnesses disagreed, saying that the fact there have been several prospective sources of funding for most scientific proposals has been one of the great strengths of American science. If, as Guyford Stever said, the support of basic scientific research is nearly a Federal monopoly, it may be essential not to leave the nurture of any scientific field entirely in the hands of a single agency. Eliminating overlaps may be a threat to innovation.

In any event, the issue is one involving all Federal agencies, not the Foundation alone, and if and when it is addressed should probably be addressed on a government-wide basis.

Rustum Roy:

Meanwhile, the great American invention, of the multiple sources of funding, which was the truly American innovation, that, I think, is endangered. (754, 755)

Richard Atkinson:

The National Science Board has stated the policy and I am in agreement with it; namely, that one agency should not be responsible for all basic research, that researchers should be able to seek support from several agencies. This insures a certain variation of opinion about what is worth funding, and what isn't, and over time if one agency has missed the boat and funded the wrong line of research, another agency will hopefully have been correct in identifying the right one. (284)

VI. Findings and Recommendations

A. SUPPORT OF HIGH-QUALITY RESEARCH

1. Finding: Procedures relying on peer review for evaluating applications for scientific research awards can lead to the effective advance of scientific knowledge. The National Science Foundation's peer review evaluation systems appear basically sound.

No method superior to peer review has been found for judging the scientific merit of basic research proposals and the scientific competence of proposers. Appropriate peer review procedures generally lead to the support of proposals in a high quality range.

Recommendation: The National Science Foundation should continue to use some form of peer review. Congress should not require major changes at this time in the methods used by the Foundation for proposal evaluation.

2. Finding: Certain problems exist with the Foundation's peer review evaluation processes and related operations. Substantial changes in the operation of the Foundation's peer review systems have been proposed which possibly could lead to improvements in the systems' effectiveness for consistently selecting the best proposals, and in the acceptability of the systems to potential applicants, the scientific community, and Congress.

Recommendation: Some corrective actions should be taken immediately and certain proposals for substantial changes should be thoroughly investigated and instituted if judged worthy.

Details of the corrective actions and studies of proposed substantial changes are discussed in succeeding findings and recommendations.

3. Finding: Proposals for truly innovative research, which is essential to the progress of science, may possibly not be adequately funded through peer review selection procedures.

Recommendation: The National Science Board should study the support of innovative research and report to Congress.

The study should include at least: (1) a detailed analysis of the issues, starting with those covered in this report, (2) a retrospective look at some major scientific innovations—with emphasis on this century—how they were funded and how they came to be accepted, (3) an assessment of the adequacy of decision-making procedures used by National Science Foundation programs for finding and funding innovative research, and (4) recommendations, if necessary, for modified procedures or new programs designed to ensure that innovative research is funded.

B. MANAGING PEER REVIEW AT THE FOUNDATION

1. Finding: There is a clear need for firm policy guidance in the management of peer review at the National Science Foundation. Experience in science and with the scientific community as well as carefully assembled objective information are essential to the formation of sound policies governing peer review.

Recommendation: The National Science Board should have primary responsibility for the establishment of policies governing peer review at the National Science Foundation.

In this recommendation the Subcommittee reaffirms the Board's legislated charge from Congress to set Foundation policies. The Subcommittee is aware that the Board has been examining Foundation policies vigorously in recent months and applauds this activity. Because of the Subcommittee's responsibilities for oversight and legislation concerning the Foundation, it is desirable that the Board turn its attention promptly to the Subcommittee's recommendations for Board actions.

2. Finding: There may be serious future problems with the Foundation's operation caused by the large number of competent scientists competing for limited funds.

These potential problems include general dissatisfaction with the Foundation on the part of the scientific community, overloads on the Foundation staff causing poor proposal evaluation, and missed opportunities caused by good scientists dropping out of the race for funds. The overload problem may already be significant.

Recommendation: The National Science Board should establish an internal Foundation program to monitor problems arising from the mismatch between the size of the scientific community and the amount of Foundation funds available for support of that community, and should report periodically to Congress.

Initial reports should deal with what is being monitored and why, and with the overload problem.

3. Finding: The communication of Foundation policies within the Foundation and with the scientific community at large should be improved.

Examples of staff actions contrary to Foundation policy were given at the hearings. Although the Subcommittee does not believe such actions are widespread, the compendium of policy and procedure memoranda submitted by the Foundation, because of its size and lack of organization, gives the Subcommittee little reassurance that the staff can stay abreast of current policies even with the best intentions. The Subcommittee believes that the scientific community should be able to understand and stay current with Foundation policies. At present there is no way such understanding can be easily acquired.

Recommendation: The Foundation should prepare an organized compendium of its policies in writing and assure that it be widely available.

The form and content of the compendium should have the approval of the National Science Board.

The Subcommittee suggests, without being prescriptive, that: (1) information about policies be separated from information about procedures; procedural information is less important and apt to change more quickly, it need not be in the compendium; (2) the compendium should be in a form that may be easily updated; and (3) copies of the compendium should be available to all Foundation staff members and to the public.

4. Finding: Performance of the staff of the National Science Foundation has been a key determinant of the Foundation's performance in the evaluation of proposals. The Subcommittee believes the staff is generally dedicated, competent, and honest.

There have been instances of staff mistakes and failures of judgment, but the Subcommittee is largely of the opinion that these are as infrequent and isolated as any human endeavor in a large organization will allow.

Recommendation: Because of the central importance of the staff, the potential effects on staff of major changes in the Foundation's decision-making processes for individual awards should be explicitly considered before such changes are made.

5. Finding: The reviewing of proposals by persons outside the Foundation should be distributed widely among competent potential reviewers.

This is already Foundation policy, and, on a Foundation-wide geographic basis, rather broad distribution appears to have occurred. There are, however, no systematic methods employed by the Foundation for assuring wide distribution or determining whether any given reviewer has been too frequently used.

Recommendation: The Foundation should devise systematic methods of ensuring that competent reviewers are identified and used regardless of institutional affiliation or geographical location. No reviewer should be overused in relation to his or her abilities.

The Foundation's management information system, the Subcommittee understands, has (or can readily be modified to have) information in it concerning reviewers which should make the execution of this recommendation a fairly straightforward matter not adding appreciably to the staff workload.

6. Finding: Strong arguments have been put forward for more extensive Foundation use of peer panel review.

Increased reliance on peer panel review was the most convincingly supported major change proposed for the Foundation's peer review systems.

Recommendation: The National Science Board should study the extent to which the Foundation should rely on peer panel review and report to Congress.

The Subcommittee itself does not feel it has sufficient information or experience with the operation of peer review systems to come now to a definitive conclusion on this matter. The Subcommittee does believe, however, that the National Science Board should give the increased use of peer panels very serious consideration.

As part of its study the Board should determine the feelings of the scientific community.

7. Finding: The philosophy of policing the National Science Foundation's peer review system should be based on trust of the Foundation's staff and reviewers, combined with vigilance over the system to assure that trust is warranted.

The Subcommittee observes that:

(a) Peer review systems based on trust allow more latitude for staff discretion and, hence, allow better performance than those based on rigid, highly structured procedures.

(b) A staff which is not trusted is unlikely to take pride in its work and will therefore perform less well than a trusted staff.

(c) Reviewers may drop out of the peer review system if they feel they are not trusted.

(d) A peer review system replete with a variety of checking mechanisms is apt to be inefficient, although no system for the allocation of funds is likely to operate properly in the absence of checks.

(e) The public is not well served if the oversight of a Federal granting system relies on the absence of indications that things are going wrong rather than the presence of indications that the system is working properly.

Recommendation: The National Science Foundation should perform random audits of the decision processes used for individual grants. The Foundation should report to Congress describing the system it uses for this type of audit.

These audits should be performed in sufficient detail to address questions of relations among Foundation staff members, applicants, and reviewers. Members of the auditing staff should not normally have responsibilities in the process of decision-making for individual awards. The audits will not replace any activities of the General Accounting Office or other Congressional arms. Further aspects of vigilance over operation of the Foundation's peer review system are described in other findings and recommendations.

8. Finding: Congressional review of individual National Science Foundation awards would introduce serious problems into the government's support of science.

The problems include:

(a) Congressional review would tend to politicize the award decision-making process and turn it away from the support of proposals on their merit.

(b) Congressional review would tend to make the Foundation less willing to fund innovative ideas.

(c) Congressional review would further lengthen the time it takes applicants to obtain funding and proceed with their research.

Recommendation: Congress should not require Congressional review of individual research awards.

9. Finding: It may be necessary to proper Congressional oversight for the Subcommittee on Science, Research and Technology of the House Committee on Science and Technology and the Subcommittee on the National Science Foundation of the Senate Committee on Labor and Public Welfare to examine certain confidential information of the Foundation.

Such confidential information would include peer reviews and the identification of which peers reviewed a given proposal. Although the General Accounting Office has had access to and used such information, to settle future controversies of the type that were raised at the hearings, these two Subcommittees may need to examine such information firsthand.

Recommendation: These House and Senate Subcommittees should work with the Foundation to establish procedures whereby the Subcommittees can have effective access to certain confidential information of the Foundation. The procedures should be designed to maintain the highest degree of confidentiality of the information that will allow effective Congressional oversight.

The Director of the Foundation has already indicated his willingness that this recommendation be implemented.

C. INFORMATION EXCHANGE AND APPEALS

1. Finding: Openness of Foundation operations and the effective evaluation of proposals by the Foundation are both desirable.

Recommendation: The greatest degree of openness of the Foundation's award decision-making process consonant with effective proposal evaluation and reasonable efficiency should be achieved.

2. Finding: In keeping with the policy of maximum feasible openness, the recent decision of the National Science Board to publish a list of reviewers used by the Foundation is laudable.

Recommendation: The National Science Board should study the effects of publication of the list and consider whether publication of the list in a less aggregated form might be desirable.

3. Finding: Information concerning the critical problem of effects on the Foundation's peer review system of the level of confidentiality in which peer reviewer's names and verbatim comments are held is inadequate for making sound judgements on what that level of confidentiality should be.

Recommendation: The National Science Board should collect further information concerning effects on the peer review system of the level of confidentiality in which peer reviewers names and verbatim comments are held. The Board should report the information and any conclusions that may be drawn from it to Congress. Further changes in the level of confidentiality of the Foundation's peer review system should be made slowly if at all.

The Subcommittee observes that there appears to be no immediate need for changes in the level of confidentiality. The Board's resolution of June 1975, changing this level took effect January 1, 1976. The Board's information collection efforts should include attempts to obtain quantitative data (the fraction of requested reviews that get done, average time between request and receipts of reviews, etc.) which will illuminate effects of the change. The Board should also collect opinions from the scientific community about the confidentiality question. The Subcommittee understands the Board has already begun collecting the latter type of data.

4. Finding: Each applicant for a National Science Foundation award should have easy access to a description of the rationale for the decision taken on the application and a description of the decision-making process itself.

It is not clear that applicants have had adequate access to such information in the past.

Recommendation: The Foundation should include in each letter announcing a funding decision to an applicant either a statement of the methods and rationale of the decision or a statement that such information will be provided on request.

5. Finding: Strong arguments have been made both for and against have in a formal method for making appeals to decisions on award applications at the National Science Foundation.

Recommendation: The National Science Board should study the question of whether the National Science Foundation should have formal procedures for considering appeals of decisions made on award applications and should report to Congress.

This study should be coordinated with the study of the support of innovative research recommended earlier. None of the specific appeal procedures proposed by witnesses displayed compelling characteristics to the Subcommittee on a first examination.

D. DISTRIBUTION OF FUNDS

1. Finding: There is division of opinion among members of the Subcommittee concerning the desirability of requiring that the geographical distribution of National Science Foundation funds meet some standard of evenness. Moreover, questions of the geographical distribution of Federal funds for scientific research should be considered on a government-wide basis, including all agencies providing significant amounts of money for scientific research, not only the Foundation.

Recommendation: If Congress undertakes studies of the geographical distribution of funds for scientific research by any Federal agency or agencies, such studies should explicitly put support by one agency in the context of total Federal support.

The Subcommittee is, nonetheless, mindful of the requirements of Public Law 81–507, Section 3(e), the organic Act of the Foundation, and cautions the Foundation that it has special statutory duty to avoid undue concentration in its grant decisions.

2. Finding: There are indications, not contradicted by available information, that research at undergraduate-teaching institutions without graduate departments (colleges) may not be adequately funded by the National Science Foundation.

This finding applies to research awards of the Foundation only. There do not appear to be problems with the overall distribution of education awards by the Foundation to colleges.

Recommendation: The National Science Board should study the funding of research at colleges by the Foundation and report to Congress.

The study should provide data on the distribution of Foundation research funds to colleges, analyze the data to determine the suitability of the distribution, and give conclusions and recommendations for Foundation procedures, as indicated. This study should be coordinated with the recommended monitoring by the Foundation of problems arising from the mismatch between the size of the scientific community and the amount of Foundation funds available for support of that community.

3. Finding: Although it is widely acknowledged that the best scientists in each generation should be identified and funded whenever possible and that employment problems for young scientists are currently severe (and likely to remain so in the foreseeable future), there is little information available about the distribution to young scientists of funds for scientific research or about the effects on science of the difficulties of young scientists.

Recommendation: The National Science Board should study the support of young scientists and report to Congress.

The study should be coordinated with the recommended program to monitor difficulties caused by the mismatch between scientists and funds. The study should include quantitative measures of the support of young scientists by the Foundation over a period of time.

E. OTHER

1. Finding: Evidence presented at the hearings which purported to show that the Foundation's Metallurgy and Materials Section has distributed funds poorly is highly questionable.

The primary reasons that the evidence is questionable are: (1) citation analysis alone was used to produce a measure of scientific ability, but citation analysis standing alone appears to be inadequate for that purpose, and (2) to be meaningful, an analysis of funding patterns must encompass all agencies providing support. Additionally, many issues concerning technical aspects of the evidence have been raised. It was not clear, however, whether the Foundation had adequately filled requests by the principal witness for information. The following recommendation addresses that point.

Recommendation: The Foundation should fill reasonable requests for data concerning the distribution of funds by the Metallurgy and Materials Section within the constraints of the Foundation's policies concerning the confidentiality of such information.

2. Finding: The extent to which the fields of scientific research supported by various Federal agencies should be allowed to overlap is open to question.

Arguments are strong that the overlap should be rather extensive.

Recommendation: Congress should not propose or acquiesce to reductions in the overlap of fields of basic scientific research supported by various Federal agencies without further investigating the advantages and disadvantages of such overlaps.

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