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Peer Review and the Support of Science

A statistical analysis of the evaluative procedures on which the National Science Foundation bases its funding decisions provides no evidence to substantiate recent public criticisms

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For more than 25 years the National Science Foundation has played a major role in the expenditure of public money for the support of science in the U.S. Currently the NSF accounts for about 20 percent of the funds distributed by the Federal Government for basic scientific research and more than 30 percent of the Federal funds allocated for such research at universities. The NSF awards its grants on the basis of a decision-making process commonly known as peer review. The term is derived from the fact that the Government officials responsible for deciding which investigators receive grants rely on the evaluations of other investigators in the same discipline.

In recent years the peer-review system has been attacked for a variety of reasons by certain members of both the scientific community and the Congress. Hearings on the alleged inequities of the peer-review system were held two years ago by a subcommittee of the House Committee on Science and Technology.

In an effort to assess the validity of the public criticisms of the peer-review system raised in the Congressional hearings and elsewhere we have been engaged for more than a year in a sociological study of the operation of the peer-review system at the NSF. This study, which is being conducted for the National Academy of Sciences, is supported by grants from the NSF: we have nonetheless had complete autonomy from the NSF in conducting our research. Our results to date have yielded little evidence in support of the main criticisms that have been made of the peer-review system. On the contrary, we have tentatively concluded that the NSF peer-review system is in general an equitable arrangement that distributes the limited funds available for basic research primarily on the basis of the perceived quality of the applicant's proposal. In particular. we find that the NSF does not discriminate systematically against noneminent scientists in the ways that some critics have charged. This is not to say. of course, that there are not errors in individual cases.

How does the NSF peer-review system work? To begin with. a scientist who wants to obtain NSF funds prepares a written proposal describing his past research. his qualifications and the new research he intends to do if he receives funds from the NSF. This proposal is usually submitted to the NSF through the scientist's institution. in most cases a university.

The staff of the NSF is divided into approximately 80 program areas corresponding to the various scientific disciplines and subdisciplines. (The chemistry section. for example. is divided into eight different programs.) When a research proposal comes to the NSF. it is assigned to the appropriate program and is thereafter handled by an employee of the NSF called the program director. On receiving a proposal the program director generally looks it over to determine its specific subject area. He then selects a number of reviewers who are sent the proposal by mail. The reviewers are asked to rate the proposal as being excellent, very good, good. fair or poor and in support of their rating to present written comments evaluating the proposal. In some programs an independent evaluation of the proposal is also made by a panel of scientists who meet with the program director three times a year in Washington.

The NSF explicitly states to its reviewers the criteria that should be applied in evaluating the proposals. The main criteria are (1) the significance of the scientific investigation described in the proposal. (2) the ability of the applicant to carry out the proposed research and (3) the capacity of the applicant's institution to support the type of research in question. Where all these factors are roughly equal. another set of criteria. including the geographic location of the applicant's institution. may be considered. Heavy emphasis is placed on the quality of the work described in the proposal and on the past research performance of the applicant.

The most fundamental criticism made of the NSF peer-review system is that it leads to inequitable decisions. Critics charge that scientists who are most capable of advancing science are sometimes denied grants and that scientists who are doing less significant work are given grants. Former Representative John B. Conlan of Arizona, for example. asserted at the Congressional hearings that peer review is essentially an elitist system run primarily for the benefit of a clique of eminent "old boys." He said: "I know from studying material provided to me by the 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.. .. Jt is an inces-

tuous '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."

Critics in and out of Congress maintain that the main organizational condition that gives rise to this unfair distribution of support is the extraordinary power in the hands of the program directors to decide who should get funds. The program director is alleged to be at the center of the old-boy network in which reviewers favorably evaluate the proposals of their friends, eminent scientists favorably review the proposals of other eminent scientists and funds are denied to scientists who are not part of the exclusive old-boy system.

Further abuse is said to be possible because the reviews received by the program director are only advisory. leaving him free to ignore them. and because the program director can predetermine the outcome by selecting a biased group of reviewers. The critics argue that knowledgeable program directors deliberately select reviewers who will be either hard or easy on a particular proposal. Even if

STATISTICAL ANALYSIS of 3,769 peer-review ratings given by various **mail** reviewers to 1,200 applicants for basic-research grants from the National Science Foundation in the fiscal year 1975 was aimed at testing the "old boy" hypothesis, which holds that the proposals of eminent scientists are apt to be rated more favorably by eminent reviewers than by otber reviewers. The ratings in the 10 different program areas studied were first converted into standard scores in the following manner: Within each field the mean rating was set at zero, and the rating received by an applicant was then expressed in terms of the corresponding number of standard deviations above or below the mean rating. A high number means a comparatively favorable rating, and vice versa Both tbe applicants and the reviewers were separately classified according to the prestige of their current academic department, as determined in an independent survey. Thus the entry in the upper left-hand corner of the table signifies that there were 83 reviews by reviewers in high-ranked departments of proposals submitted by applicants from high-ranked departments; on tbe average these reviews yielded ratings that were .05 of a standard deviation above the mean. Since it appears that proposals from applicants in high-ranked departments are actually rated lower by reviewers from high-ranked departments than by reviewers from lower-ranked departments, in this sample at least the data offer no support for the old-boy hypothesis. The analysis does sbow that applicants from high-ranked departments are slightly more likely to receive favorable ratings than are those from unranked departments, but there is no evidence that this outcome is the result of inequitable treatment.

NSF PROGRAM DIRECTORS appear to rely heavily on the evaluations of the peer reviewers in deciding whether or not a research proposal k to he funded. As the chart at left shows, among the 382 applicants who received comparatively high ratings from the mail reveiwers 92 percent were awarded grants, whereas among the 390 receiving low mean ratings only 10 percent received grants. Similarly, as the chart at right shows, among those proposals that received comparatively high ratings from an independent panel of peer reviewers 84 percent were funded, whereas among those that received low panel ratings only 12 percent were funded. Evidently peer-review ratings are the most important determinant of the program director's decision.

the program director feels compelled by the reviews to support a proposal he dislikes. he can effectively stifle the research by reducing the size of the budget. The program director can supposedly do so because there are no effective checks on his power either inside or outside the NSF. In short. there is no appeals system to challenge the decisions made by the program director.

Critics assert further that the NSF cloaks its activities in secrecy in order to protect the old-boy system, refusing to allow Congressmen or others to see verbatim reviews or to learn the names of the reviewers of particular proposals. This protective shield of confidentiality enables the old-boy system to function unchecked and prevents effective oversight of the NSF by Cengress. The ultimate consequence is that the peer-review system actually stifles innovative research. since the eminent scientists who serve as reviewers are likely to reject ideas that differ from their own.

In our study of the peer-review system we decided to limit ourselves at first to an examination of how peer review works in just those NSF programs responsible for the funding of basic research. We have not studied peer review in the NSFs applied-research programs or in its educational programs. Furthermore, we chose a sample of only 10 basic-research programs for detailed study: algebra. anthropology. biochemistry. chemical dynamics. ecology. economics. fluid dynamics. geophysics. meteorology and solid-state physics. Because our intensive analysis included only about an eighth of the NSFs basic-research programs our results may not be generalizable for the entire organization. We are currently conducting follow-up studies of other programs.

Our investigation has combined both qualitative and quantitative sociological techniques. We began by conducting 70 in-depth interviews with scientists involved at all levels of the peer-review system. including program directors. former program directors, mail reviewers, review-panel members and supervisory-level NSF officials. We also scrutinized more than 250 specific research proposals. read all of the peer-review comments on those proposals and examined all of the correspondence between the applicant and the program director. In some cases in which our analysis of the applications raised specific questions about how the peer-review system worked in that particular situation we went back and reinterviewed program directors with the files in hand.

In addition, we conducted a quantitative analysis of 1.200 applicants to the NSF in &he fiscal year 1975. (Roughly half of the applicants were ultimately awarded grants.) The purpose of the quantitative study was to identify those characteristics that were correlated with the receipt of a grant from the NSF. Were Representative Conlan and the other critics of peer review correct in their assertion that eminent scientists have a great advantage in the competition for funds and that less eminent scientists. particularly younger ones, are at a serious disadvantage? We shall try to answer this question by summarizing below some of the results obtained so far in our study.

One of the main charges of the critics is that the NSF program director can predetermine the outcome of the peer-review process by sending a proposal to scientists who he knows in advance are biased either in favor of the proposal or against it. We shall call this view the old-boy hypothesis. Presumably the proposals of eminent scientists who are members of the old-boy network are sent to other eminent scientists who give their eminent colleague a favorable evaluation. In return. of course. the reviewers expect reciprocity when their proposals arc sent to other members of the old-boy club. Equally important, the proposals of less eminent scientists. who are not part of the network. are sent to scientists who will give them lower evaluations than they deserve. Although we have no direct evidence that the program directors either do or do not select reviewers with a certain outcome in mind. we can see if the outcomes are consistent with the old-boy hypothesis. Are the proposals of eminent scientists actually rated more favorably by eminent reviewers than by other reviewers?

To test this hypothesis we classified both the applicants and the reviewers according to the prestige of their current academic department. as determined by a survey conducted in 1969 by the American Council on Education. The ratings given to the applicants by the reviewers in the 10 programs we studied were standardized separately before being combined into one large table [see *illustration on preceding page*]. For example. there were a total of 83 cases in which an applicant from a high-ranked department had his proposal reviewed by someone who was also from a high-ranked department. The number associated with this particular applicant-reviewer pair (+.OS) indicates the average rating (in standardized units) given by high-ranked reviewers to proposals from high-ranked applicants. The higher the number. the higher the rating.

In general we found that applicants from high-ranked departments received slightly better reviews of their proposals than applicants from medium-ranked and low-ranked departments. Furthermore, it appeared that high-ranked reviewers tend to be slightly more lenient with proposals than low-ranked reviewers are. These results. in and of themselves. cannot be interpreted as offering support for the old-boy hypothesis. For example, the fact that eminent scientists tend to get higher ratings could simply be a result of the higher quality of their proposals or of the belief on the part of the reviewers that the eminent scientists are in fact better able to carry out the proposed research.

In order to explore the matter more deeply we next conducted a statistical analysis of variance that compared the observed mean rating for each applicant-reviewer pair with the expected mean rating. assuming no bias. The results of this analysis indicated that in general reviewers from high-ranked departments were not disproportionately favoring proposals from applicants in similarly high-ranked departments. We conducted this analysis separately for each of the 10 programs. In only one

program were reviewers at high-ranked departments detectably more lenient toward the proposals of their colleagues at similarly high-ranked departments.

Another statistical analysis of variance tested the reviewers' bias in terms of geographic location and of the relative eminence of the reviewer and the applicant. It showed no significant tendency for scientists in one part of the country to favor proposals from colleagues in their own region or for eminent scientists to favor the proposals of eminent scientists over the proposals of less eminent scientists. Thus even if it were true that the program directors at the NSF were attempting to manipulate the outcome of the peer-review process by their selection of reviewers (and our qualitative findings indicate that it is unlikely). the quantitative data suggest that they have not been successful.

One reason it is difficult to test the validity of the old-boy hypothesis is the absence of conceptual clarity in the charge. What is referred to by the old-boy label? There are at least three possibilities. The term could refer to investigators with a common view of their field who will only appraise favorably work that is done by people with similar views. It could refer to networks of friendships: scientists who know one another. who "grew up" together or attended the same schools and who tend to fraternize and also to favor one another's proposals. It could refer to social position: scicntists at a given level of eminence might tend to favor the proposals of others who are similarly situated in the hierarchy of science. even if they have no personal contact with them. Critics of the pecr-review system never specify clearly which form of old-boyism is undermining the peer-review system. The data reported here allow us to examine the assertion that persons of similar rank. similar intellectual background and similar repute favor one another's proposals. but we do not have in hand data for examining forms of old-boyism that may be connected with friendship patterns.

How do the characteristics of the applicants affect the peer-review ratings they receive? Critics of the peer-review system say that regardless of the quality of proposals eminent scientists enjoy an advantage over those who are

CHARACTERISTICS of successful applicants for NSF grants in 1975 are summarized in these bar charts. Among the characteristics represented here are rank of Ph.D.-granting department (*top*), rank of current department (*second from top*), number of scientific papers published between 1965 and 1974 (*middle*), number of citations to work published between 1965 and 1974 (*second from bottom*) and to work published before 1965 (*bottom*).

OTHER CHARACTERISTICS of successful applicants for grants io 1975 are represented in these charts. Characteristics include past five years' funding record *(fop left)*, type of academic department *(top ri&)*, academic rank *(bottom left)* and professional age *(bottom right)*.

not eminent. In the final analysis. these critics contend, the peer-review system results primarily in eminent scientists at high-ranked departments having an unfair advantage in grant approval over less eminent scientists at lower-ranked departments. To test this "rich get richer" hypothesis we combined the applicants from all 10 programs into one large standardized sample. The 1.200 applicants in the sample were characterized by nine variables that established their status in the social system of science. Each of these characteristics was then tested separately to sec if it provided evidence in support of the rich-get-richer hypothesis.

For example. we characterized the applicants according io the graduate departments from which they obtained their doctoral degree to see if scicntists that come from prestigious Ph.D.-granting departments tend to get higher ratings than those who come from less prestigious departments. The applicants were also classified according to their current academic departments in order to test the assertion that applicants in high-ranked departments have an undeserved advantage over applicants in low-ranked departments. We classified the applicants according to their current academic rank in order to see if assistant Professors are any less likely to receive grants than associate professors or full Professors. In addition we classified all the applicants according *to* their professional age. their published scientific works, the number of citations of their published works and whether or not they had received NSF funds in the past.

The rich-get-richer hypothesis would suggest the existence of strong correlations between all of these variables and the ratings the applicants received on their proposals. There arc. indeed, reasons other than old-boyism for this expectation. For one thing scientists who in the past had done research that other scientists had valued highly could reasonably be expected to write proposals that would be more likely to be rated highly. Moreover, since the NSF explicitly instructs reviewers to regard past performance as one of the major criteria in determining a rating. reviewers could be expected to give higher ratings to scientists with a superior "track record."

The data. however. provide little support for the rich-get-richer hypothesis. Our results show only weak or moderate correlations between each of the nine "social stratification" variables and the ratings received on proposals. The most highly correlated variable was the number of citations in the 1975 *Science Citation Index* of work published between 1965 and 1974. Even this rough measure of the significance of recently published work is not correlated very strongly with the ratings. explaining only 6 perccnt of the variance in the ratings. The correlations between the other variables and the ratings are all surprisingly low. explaining only an additional 5 percent of the variance in the ratings. In the end 89 percent of the observed variance in the ratings is left unexplained by the nine variables.

These results ran so counter to our expectations that at first we suspected they might have been caused by some methodological error. A thorough review of our correlation and regression procedures, however. left the results intact. In fact, the validity of our findings has been corroborated by a recent study conducted by members of the NSFs own chemistry section. Their independent analysis yielded results that were virtually identical with our own. It is difficult to avoid the conclusion that there is no substantial correlation between peer-review ratings received by applicants for NSF grants and statistical indicators of their professional status or past scientific performance. Scientists whose published work is frequently cited were only slightly more likely to receive favorable ratings than scientists with only a few citations or none.

It still appeared possible. however. that the weak correlations we observed could have resulted from a lack of agreement among the reviewers. For example. if an applicant with a large number of citations of his work received very favorable ratings from some reviewers and very unfavorable ones from others, that could account for a weak or nonexistent corrciation between citations and ratings. How much agreement was there among the various reviewers of a given research proposal?

To answer this question we first determined the mean standard deviation of the reviewers' ratings. a quantity that can be taken as an approximation of the degree of agreement in a given field. This number varied from a low level of .31 in algebra to a high level of .69 in ecology and meteorology. (A low mean standard deviation corresponds to a high degree of consensus. and vice versa.) This approach could itself be tlawed. however, if one were to fail to take into account the mean rating of the reviewers in each field. Clearly if thete is a general tendency in a field to restrict the range of evaluations to either high or low scores, there would be less chance for variations in the ratings. We therefore relied on a statistic called the coefficient of variation. which is simply the mean peer-review rating divided by the mean standard deviation. In general we found that there was a good deal of agreement among the mail reviewers in all 10 fields and little systematic variation among the fields. The coefficient of variation ranged from a low of .13 in economics to a high of .30 in ecology.

To test further the notion that the weak correlations we observed resulted from a lack of agreement among the re-

viewers. we examined the correlations between the mean rating received by a proposal and several characteristics of the applicant. If the weak correlations had resulted from a lack of agreement among the reviewers, the associations between mean ratings and individual characteristics would be substantially higher, since mean scores are almost invariably more strongly correlated with any given variable than are individual scores. When the mean rating was used as the dependent variable in a statistical regression analysis. we obtained results similar to those obtained in our original analysis. The highest correlation was found between citations of recent work and the mean rating, followed by the correiation between past funding history and the mean rating. Although this method of analysis had the effect of increasing the amount of variance explained by the characteristics of the applicants from 11 percent to 16 percent. the great bulk of the observed variance in the ratings remained unexplained. The new analysis supported the conclusion that the weak correlations observed were not a result of a lack of agreement among reviewers.

In short, these data suggest that the mail reviewers are not strongly influenced by the professional status of an applicant in evaluating a proposal. On the contrary. they appear to be much more likely to be influenced by their perception of the quality of the research proposed. One crucial question remained: How is the program director's funding decision related to the reviewers- ratings on the one hand and to the characteristics of the applicants on the other?

Critics of the peer-review system contend in effect that the decisions of the NSF program directors depend more on who you are than on what you propose to do. So far our data have tended to refute this version of the old-boy hypothesis. Before this refutation can be established conclusively. however. we must establish that the peer-review ratings are the single most important determinant of the program director's funding decision and that the characteristics of the applicants have little independent effect on the outcome.

The NSF states clearly that the reviews by either the mail reviewers or the panel members are advisory and the program director has the final responsibility for deciding whether or not a proposal is to be funded. Our data show that the program directors in fact rely very heavily on the evaluations of the peer reviewers. For example. among those applicants who received comparatively high mean ratings from the mail reviewers 92 percent were awarded grants. whereas among those receiving low mean ratings only 10 percent got grants. Among the group who received mean ratings in the middle ranges about hall were awarded grants Similarly. among those applicants who received comparatively high panel ratings 84 percent were funded, and among those who received low panel ratings only 12 perccnt were funded [*see illustration on page 36*].

What types of scientists were successful in receiving grants from the NSF in 1975? Of those applicants who obtained their degrees from the highest-ranked graduate departments 62 percent were awarded grants. compared to 38 percent of those who were graduated from the lowest-ranked departments. Similarly. 74 percent of the applicants currently employed in the highest-ranked departments were funded. compared with 38 percent currently in either unranked departments or nonacademic institutions.

Recent NSF funding history and frequency of citations of recent work both had a moderate influence on the probability of receiving a grant. Among applicants receiving the most citations to recently published work roughly three-quarters were awarded NSF grants; among those receiving the least citations of recent work less than a third received grants. The number of papers published and the number of citations of work published before 1965 were less strongly associated with the receipt of a grant. Other attributes of the applicants. such as their professional age or their academic rank. had a minor effect on the probability of receiving a grant.

The effect of professional age on the probability of receiving an NSF grant is

INDEPENDENT EFFECTS of a scientist's past achievements on the probability of receiving an NSF grant are represented in thi chart and the one on the next page The applicants were divided into three groups: those who received comparatively high mean ratings from mail reviewen, those who received medium mean ratings and those who received low mean ratings. Within each category tht probability *that* particular scientists—in this case those with different numbers of citations of their recent work—would receive grants was then canculated. The results show that scientists whose work & frequently cited have a slight competitive odvantage in the competition for funds.

SIMILAR ACCUMULATIVE ADVANTAGE is indicated, among those scientists whose proposals received medium or low peer-review ratings, for applicants who had been funded by the NSF in the past five years. Again. a good record appears to produce a slight advantage.

particularly noteworthy. When we began our study many scientists indicated that they believed it was more difficult for younger scientists to obtain NSF funds. Our interviews with program directors. on the other hand. revealed that they perceived just the opposite. Because there is a commitment on the part of the NSF to help young. talented scientists get started. several program directors said that in the case of roughly equal peer reviews they would prefer to fund younger applicants. As it happens, the perceptions of both the applicants and the program directors are mistaken. The data we have gathered indicate that professional age has almost no effect on either the peer-review ratings or the final funding decision.

The overall pattern of our data suggests that scientists with an established track record. many scientific publications. a high frequency of citations. a record of having received grants from the NSF and ties to prestigious academic departments have a higher probability of receiving NSF grants than other applicants do. Nevertheless. the granting process is actually quite open. and there is nothing approximating a scientific caste system. Even among the most frequently cited scientists who apply for support an appreciable number do not receive grants. and among the group with the fewest citations to their work a significant number do receive grants. There is no evidence that scientists who have received grants in the past are guaranteed continued support. or that those without a past funding record have no chance of obtaining current NSF funding. Indeed. given the heavy emphasis the NSF places on past performance as one of the two most important criteria in evaluating research proposals. it is somewhat surprising that measures of past scientific performance do not show a stronger influence on the probability of receiving a grant.

It should incidentally be noted that the data presented here allow us to answer two distinct questions. The first is: How well do the social characteristics of scicntists and their previous record predict peer-review ratings and the probability of funding in general. that is. when we examine the entire sample of applicants? The second is: Are there substantially different probabilities of receiving high ratings or a favorable decision for the most eminent applicants compared with the least eminent applicants. that is. when we compare relatively small subsets of the sample? The answers can be different depending on which of these two questions we ask.

For the sample as a whole status differences are not good predictors of ratings. Consider a concrete example of what we mean by focusing again on the relation between the rank of an applicant's current department and the final funding decision. First recall that 55 percent of all 1.200 applicants received NSF grants; if one had to predict whether an individual applicant had received a grant. to predict in every case that he had received one would make one right on 55 percent of the applicants and wrong on 45 percent. The question is: How does knowledge of the rank of an applicant's department increase the ability to predict whether he received a grant? To estimate this we examine each of the five classifications of departmental rank. In the two bottom categories, where a majority did not obtain support. we would guess that all applicants did not receive grants; in the other three categories. where a majority received support, we would do better to guessthat all received support. That would result in correct predictions in 63 percent of the cases. When we subtract from this total the proportion (55 percent) that we would have guessed correctly without any information about the individual's departmental affiliation, we get an estimate of the increase in predictability that results from knowledge of rank of department: in this case an increase of 8 percent. which is not an extraordinary increase in predictability.

Suppose. on the other hand. we want to know whether scientists in the highest-ranked departments have a better chance of receiving NSF support than those in unranked departments or in a nonacademic setting. If we compare the percentage difference between these extreme subgroups. we find a substantial 36-point difference. In other words. some percentage differences do appear large in the extremes. but that does not mean the characteristic is a good predictor of a decision for the entire sample. Of the variance that can be accounted for in funding decisions, the peer-review rating is by far the best predictor.

The well-documented social process referred to by sociologists of science as "accumulative advantage" would lead one to expect that eminent scientists have a better-than-average chance in the competition for NSF funds. Accumulative advantage in this context means that a scientist who has been rewarded at one stage in his career has an enhanced probability of being rewarded at a later stage. regardless of the quality of his scientific work in the interim. The concept explains in part the increasing inequality in rewards that is observed as an age cohort of scientists moves through time.

According to the concept of accumulative advantage. the initial social status of a scientist influences the probability of his obtaining a variety of forms of recognition. including the esteem of his colleagues. an association with centers of excellence in the academic world and the resources and facilities necessary for productive scientific work. For example, young scientists who are trained in the best university science departments. and particularly those who have been apprenticed to leading scientists. have a better chance than less well-placed students of equal ability to secure first jobs at prestigious institutions. Once established in these positions they have a better chance than their peers to obtain support for their research. With greater support they have an enhanced opportunity for making significant scientific discoveries and publishing the results. And

once the results are published they have still greater chances for futurc success. To the extent that this process works to the advantage of scientists who are initially well placed in the social system of science it also works to the disadvantage of their peers who are not so fortunate.

By taking the mean peer-review rating rcceived by an NSF research proposal as a rough measure of the quality of the proposal we attempted to determine the independent effect of a scientist's past achievements on his receiving a grant. We first divided the applicants into three groups: those who received comparatively high mean ratings. those who received medium mean ratings and those who received low mean ratings. Within each category we calculated the probability that scientists who had had different numbers of citations of their recent work would receive grants. We then considered only the group of proposals that received the highest peer-review ratings. Of this group 100 percent of the quintile with the highest number of citations were awarded NSF grants. In the lowest quintile 77 percent received grants. This finding leads to two conclusions: (1) the mean peer-review rating is a far more important determinant of whether a scientist receives a grant than is the number of citations of his recent work. and (2) within each category of mean ratings the number of citations of recent work has only a slight influence on the probability of approval.

We next considered the cases of those scientists whose proposals received low ratings. A substantial majority of all the proposals in this category were declined. but the number of citations made little difference. Within the group of proposals that received low ratings 16 percent of the scientists with the most citations received grants. compared with 3 percent of those who received the fewest citations.

The foregoing data offer some limited support for the concept of accumulative advantage. Scientists whose recent work has been frequently cited have a measurable advantage in the competition for current funds: this advantage is. however, very slight. The process of accumulative advantage is somewhat more evident among those scientists whose research proposals received medium peer-review ratings but who had been funded frequently by the NSF in the past five years. Among scientists whose proposals received medium ratings. for example. 61 percent of those who had been funded within the past five years were awarded a current grant. whereas only 41 percent of those who had not received funds from the NSF in the past five years were awarded a current grant. Clearly a good funding record gives rise to a slight competitive advantage.

We also examined the independent effect of an applicant's current academic department on the probability of his being awarded an NSF grant. Here the story was somewhat different. The rank of a scientist's current department apparently has almost no effect on the probability of his receiving a grant independent of the peer-review ratings received by the applicant's proposal. Of the scientists in the highest-ranked departments whose proposals received comparatively low ratings 6 percent were awarded grants, a figure no different from that found among applicants in lower-ranked departments. In the competition for current funds. therefore. a scientist's past performance as measured by citations of his work and his recent NSF funding record does lead to a very slight accumulative advantage. but his academic affiliation does not appear to give him any advantage.

The results of our study of the operation of the peer-review system in the basic-research programs of the NSF are consistent thus far with other recent findings in the sociology of science. which suggest that the scientific enterprise is an exceedingly equitable. although highly stratified. social institution in which the individuals who produce the work that is most favorably evaluated by their colleagues receive the lion's share of the rewards. Further study of the equity of research-fund distribution will address two basic problems not yet considered. In the first phase of our study we relied on the peer-rcview ratings elicited by the NSF program directors as an indicator of quality and found those ratings were strongly related to the actual funding decision; now we are submitting proposals to independent review panels in order to obtain independent appraisals of their quality. Finally. having learned that peer-review ratings are strong predictors of funding decisions. we are interested in whether or not they also are good predictors of future scientific performance. and so we are studying how the ratings and recent research performance compare as predictors of future research performance.

NO INDEPENDENT EFFECT was delectable in this similar statistical analysis, which measured the influence of an applicant's current academic department on the probability of being awarded an **NSF basic-research grant.** Apparently **current academic affiliation does not give an applicant any competitive advantage independent the peer-review ratings that were received by his research proposal.**