By all indications, the graduate education of scientists in the United States produces knowledgeable, competent individuals who are well versed in their fields and who can do research. We do not, however, know how effective graduate education is either in providing training or in engaging student interest in the ethical issues and questions about values that concern the practitioners of research, their sponsors, and their critics. With the exception of a few courses or seminars in philosophy of science or the ethics of research, it seems clear that in contrast to the explicit ways through which research methodologies are taught, issues related to the philosophy, ethics, and values of research usually are transmitted implicitly or informally by science faculty, in ways related less to specific disciplines than to the interests of individual faculty members and the kinds of universities in which students obtain their graduate degrees. To understand this fully, it is important to understand the general context and characteristics of graduate programs in the sciences.

EDUCATION FOR RESEARCH

Individuals interested in careers in research—either as members of university faculties, in industrial or government laboratories, or in any of the other settings where research is carried out—generally pursue graduate study directed toward obtaining the PhD degree. The single exception occurs in professional schools such as medicine where the professional doctorate—for example, the MD—is considered an appropriate credential for faculty members and others involved in research. Physicians interested in research rarely enroll in PhD programs. Some have gone through combined MD/PhD programs, which are designed to enable students to pursue both degrees simultaneously, but most MDs seeking research careers usually become trained by spending several years doing research under the supervision of a senior scientist. No degree is obtained from this experience, which is more of a research apprenticeship than a formal program of training. We will examine this difference in training more critically in connection with our discussion of research misconduct.

Although different countries have evolved different concepts of the kind of education required for the certification of scholars, their common thread is the necessity for the student to demonstrate the ability to do independent research. While course work and seminars form an important part of every graduate program in the United States, programs leading to the PhD emphasize active involvement of students in research under the supervision of established scholars. It is during this process that students learn how to do the actual manipulations, calculations, analyses, and thinking that make up the day-to-day activities of research. In other words, the students become technically competent. They also learn the state of the art in the particular area they are investigating, and in their field of specialization, by intensive reading and guided discussion of the scientific literature dealing with the subject. Finally, it is during this time that graduate students acquire, usually through informal and unprogrammed activities, the values and norms of behavior—scientific, professional and ethical—that will characterize their careers.

THE ROLE OF THE FACULTY

In all of these activities, the students research supervisor—usually referred to as the major professor, doctoral adviser, or mentor—plays a critical role. Above all, the adviser is a teacher, in both formal and informal settings, of a wide range of subjects ranging from specific techniques and experimental procedures to ways of thinking about research, science, and life in general. Much of what a student learns in a graduate program is obtained by modeling ideas and behavior on those of someone who has mastered a field. There appears to be relatively little inclination on the part of universities to formalize the conditions of this relationship beyond making sure that students are assigned to advisers and that specific degree requirements are met. Some departments and graduate schools, however, have developed guidelines for faculty advisers of doctoral students. For example, the Office of Graduate Studies at Stanford recently has published Graduate Student Academic Advising Guidelines for Departments (1). In the section on “Monitoring/Advising/Mentoring,” the guidelines state:

The goal of graduate education is to train the student to do independent research and scholarship; the process includes training to think clearly and critically, to conceptualize, argue, debate, challenge and give an opinion, to understand and follow the ethics of the field; and, where appropriate, to teach.

They go on to say that mentoring...


2 Supported by Grant No. BBS 87 11082, National Science Foundation.
For the most part, however, the relationship between adviser and advisee is idiosyncratic and depends on the personalities and attitudes of the people involved. In this regard, it is important to recognize that the more research-intensive universities are characterized by the greatest amount of freedom for individual faculty members. This autonomy places almost the entire responsibility for graduate student training in the hands of the adviser, who is the major influence in designing the student’s graduate program, including the selection of and approach to a research topic, and who serves as a major role model in the student’s socialization as a scientist.

In many universities, all faculty members are eligible to serve as advisers to graduate students. In others, formal appointment, usually through a graduate school evaluation process, is necessary before faculty can become advisers. In a recent survey of fifty-four major research universities, the split between the two systems was almost exactly even(2). In either case, the principal factor in determining a faculty member’s qualifications for advising doctoral students is that faculty member’s record of research productivity, usually judged by publication in peer reviewed journals and success in obtaining research grants. The assumption is made that those who have demonstrated research experience are appropriate mentors for those who are learning to do research. But while there is general agreement that all advisers of doctoral students must be active researchers, it is not necessarily the case that all researchers are suited to be advisers of doctoral students. A faculty member, in agreeing to accept a student as an advisee, takes on a specific responsibility to provide to the student time, advice, guidance, evaluation, and the opportunity to satisfy requirements for the degree. Among other things, this means that the student’s progress toward the degree, and maturation as a scientist, must be matters of personal and professional concern to the adviser.

In principle, the entire graduate program is devoted to ensuring that students understand the process of research and can engage in it as independent scholars. Since most of the research is related to the student’s dissertation, it receives intense scrutiny by the adviser and other members of the faculty at every stage from inception of the research plan through design of the experiments to defense of the dissertation. Students learn very early that they will be expected to produce their data and defend their ideas, their procedures, their analyses, and their conclusions. Evaluation by the faculty continues both in formal courses and through committees, particularly for admission to candidacy, for which the student is subjected to an intensive examination covering the entire field of study, and for defense of dissertation at which time the student must defend his or her research often at a public or semipublic hearing. In addition, there usually is a departmental graduate committee whose role is to ensure that all students meet departmental standards, and a campuswide graduate school committee that performs a similar function for the university.

This model for the graduate education of scientists is based on the assumption that graduate advisers work with small numbers of students so that the interaction between adviser and student can be intense, individualized, and frequent. As university-based research has grown into the major enterprise it represents today, there are signs that the simple fact of growth may be changing the nature of the process. In commenting on what they term the “degradation of the master-apprentice relationship,” Broad and Wade observe that

the professors who train these graduate students and postdocs stand in a fiduciary relationship to them, teaching them the art and craft of research, guiding their interests toward problems of scientific importance, and imbuing them with the tradition of serious research. The intimate bond that often grows up between the professor and his students is grounded in intellectual curiosity and a common commitment to the truth(3).

Under current pressures, they suggest, “young researchers setting out on their careers must now find not just an intellectual master but a patron with command of a large government grant.” The patron, in turn, must “busily cultivate the appearance of success” to maintain adequate funding to meet the payroll(4). Some faculty members have become directors of large research laboratories, employing dozens of technicians and professional staff as well as many graduate students and postdoctoral associates. The pressures associated with maintaining this level of research activity, particularly in terms of funding and publication of research results, can change an atmosphere formerly characterized by one-to-one relationships between students and advisers to one in which large teams perform research under the direction of a busy, harried, and often remote supervisor.

In these circumstances, the processes and practices traditionally associated with the graduate education of scientists can be distorted to the point that they become inconsistent with the basic principles that govern all research: the shared values of a research community and the reliance on the integrity of one’s colleagues. It is these issues that we explore in the remainder of this paper.

VALUES AND ETHICAL CONCERNS

Research doctorate degrees in the sciences are awarded by approximately 285 universities in the United States. It is important to note that the top fifty of these institutions (in terms of number of degrees awarded) grant 60 percent of all degrees, and further, that the top 100 grant 83 percent of all such degrees. Thus, although a large number of institutions award these degrees, production is dominated by a relatively small number of schools, usually referred to as research universities. These are institutions whose basic missions involve intense commitments to research and graduate education. Among other things, this means that their graduate students are immersed in an atmosphere that not only reflects the values of the research community but defines those values as well. Faculty are hired primarily because of their potential as researchers, and department chairs and deans seek out such people. Admission to graduate programs is highly selective and totally controlled by faculty at the department or program level. The system is a meritocracy that values knowledge, skill, aggressiveness, competitiveness, imagination, creativity, and productivity. The new graduate student looks around and observes that the successful students, those who have access to their advisers, those who finish their programs, those who get good jobs after they graduate, are the ones who exhibit these traits and who are intensely involved, emotionally and intellectually, with their research.
As the student progresses in the program and becomes more knowledgeable about the discipline, the research community, and the university, a new set of issues begins to arise that are different from those encountered in classes. Some of these relate to group standards of behavior, the group being the particular discipline or, in some cases, the institution, department, laboratory, or even the research project in which the student is involved. Such issues may include the following: consideration of taste in the choice of research projects; the realization that some people seem to choose more significant or interesting areas for research than others; whose names should appear, and in what order, on papers representing collaborative research studies; and which journals are the best ones in which to publish. These primarily are questions of style and form, of commonly accepted norms of behavior and customarily practice within a particular research community. Thus, answers reflect field-specific concepts of significance and propriety.

There is another side to these questions that goes beyond socialization in the discipline. This involves questioning whether a piece of work is publishable at all, and if it is, whether all individuals whose names are to appear as authors have actually made substantial contributions to the research. This may introduce graduate students to the reality that political as well as scientific considerations may influence their decisions. Here again, faculty mentors play a critical role in establishing models for integrity.

In addition, this is the time when ideas are formed about the technical and ethical basis of good practice in research. The graduate student, in presenting and defending original ideas and experimental approaches to fellow students and faculty members, and in challenging what is found in the literature and in the approaches of colleagues, begins to understand in a very direct way the dimensions of the experimental method, and to develop, under the guidance of mentors, a sense of what is meant by good science. Writing about this aspect of the training of scientists, John Ziman makes the point that learning to be a scientist does not make one honest, truthful, or objective (although people with these attributes may find scientific careers particularly attractive). It does, in its best sense, produce a scientist with “very high internal critical standards for arguments within the context of his discipline” (5).

There is a different set of ethical questions that are more personal in nature and challenge individual moral standards. Should I work on projects that are classified or restricted with respect to publication in the open literature? Should I work on projects that could lead to the creation of weapons? Should I work on projects that could create new life forms? Should I, as a university-based researcher, work on projects intended to profit a certain company? These are complex questions and there is no single answer that emerges from the research community. Graduate students cannot avoid being aware that faculty members, as well as fellow students, may have strong and different views on these and related subjects. These issues are rarely discussed in a formal sense, either in classes or seminars. They are more likely to be discussed informally, in ways that do not always lead to rigorous analysis of the issues and principles. But these are issues in which differences of opinion, even if based on emotional or non-scientific foundations, are acceptable within the research community.

The reasons are fairly clear. Scientists, particularly in academic settings, zealously protect their right to choose not just their area of research but the specific kinds of projects they will work on. The factors affecting that choice are many and varied. They may range from consideration of what is most fundable through ideas about societal usefulness to simple curiosity, with the latter being perhaps the most basic motivation for doing research. If the problem is interesting enough, political, economic, or humanitarian concerns may take second place. This being the case, it is unlikely that the scientific community will establish a position on issues of this kind, although groups of scientists may actively support various positions. Recent examples of controversial topics over which the scientific community has been publicly divided include genetic engineering and the Strategic Defense Initiative. In both cases, scientific as well as philosophical differences exist.

Finally, there is a set of issues completely different from those just discussed. They involve fundamental ethical standards of research and are not matters of taste, style, or personal conviction. The research community, regardless of discipline, cannot tolerate misrepresentation of experimental results or of authorship. Scientists rely on the literature in their fields as the basis for their own work, whether that work be pointed toward challenging, corroborating, or extending reported studies. Even at the earliest stage of involvement, students understand that it is possible to misinterpret experimental data or to draw erroneous conclusions. As Ziman has pointed out, “The power of the scientific method is not that it keeps any of us from error but that by mutual criticism and persuasion, we gradually clarify each other’s intuitions, until they become part of the canon of the subject.” (6) However, for this to happen everyone must be able to assume correctly that experiments described in a research article were actually carried out, that the results reported were actually obtained, and that the individuals whose names appear as authors actually did the work and are responsible for it.

These assumptions are so basic to the nature of research that, at least until recently, they rarely have been articulated. It is unlikely that anyone, faculty or student, will actually tell the new graduate student that it is wrong to falsify data or to plagiarize someone else’s work. Everyone is expected to know that. Discussions of these topics, when they do take place, typically do not focus on the ethical issues involved, since there should be no argument or difference of opinion, but on other aspects: the reasons for this kind of behavior, the damage to science and the public perception of science when these incidents occur, the effects on the people directly involved, and the responsibility and ability of the scientific community to monitor its own activities and expose any violations.

The communal nature of scientific research, the dependence that scientists have on the absolute honesty of their colleagues in reporting their work, insures that shock waves will go through the scientific community when incidents of scientific fraud are revealed. A major outcome of such shock is that everyone in the community, from beginning students to university administrators, tries to learn what happened, to understand how it could have happened, to speculate on what the consequences are likely to be, and perhaps most important, to examine their own part of the scientific world—individually or institutionally—to see if the same thing could happen there. For individuals, this comes down to consideration of one’s own ethical imperatives (or perhaps thresholds). What would lead someone to do such a thing
Would I (could I) ever do something like that? Are there any circumstances that might push me in that direction? For institutional officials, the questions are different. Could something like that happen here? If it did, how would we deal with it? Is there any way to prevent such activities from occurring? How do we, as a collection of individuals, protect the integrity not just of our institution but of the scientific enterprise as well?

**SCIENTISTS AND SUPERVISORS**

Analysis of recent proven cases of fraud provides some answers to such questions, but only in a very limited sense. Although a number of cases, particularly in the period 1978-1988, have been widely publicized and extensively analyzed, almost none of them involved graduate students or graduate education. The vast majority concerned biomedical research, usually being carried out in a medical school environment under the conditions briefly described earlier in this paper. The culprits (e.g., John Darsee, Vijay Soman) were junior colleagues with MD degrees who were doing research under the supervision of well-regarded, heavily funded senior scientists; there was no formal adviser-advisee relationship, no graduate program, no advanced degree being sought.

In both of the cases mentioned above, investigating panels were critical of the supervisory roles of the senior scientists. An expert panel, convened in 1982 by the National Institutes of Health (NIH) to investigate charges that John Darsee had fabricated data in cardiology research performed at Harvard Medical School, ultimately laid some of the blame at the feet of Darsee’s supervisor, Eugene Braunwald, for failing to provide the kind of supervision necessary to the training of young scientists in his laboratories(7). Said Dr. Howard Morgan, who chaired the panel: “There’s probably too much emphasis on what you do once you find out something is wrong in a few cases, and not enough emphasis on what you do to provide the right kind of environment and climate in order to conduct responsible science.”(8)

Similarly, when Vijay Soman at Yale plagiarized the work of an NIH scientist and published (with his highly esteemed supervisor as coauthor) results of fabricated research, commentators were critical of the lack of close supervision provided by Philip Felig(9). By failing to review the primary data, even after allegations of data fabrication had been made, Felig provided at the very least an opportunity for his junior colleague to perpetrate his deceit(10). Felig later told a congressional subcommittee investigating scientific fraud that he had become more careful about signing his name to papers prepared by subordinates, and that he had come to believe in the importance of reviewing the original data of junior scientists, particularly those with whom he was not too familiar.

While these cases do not relate to graduate education, they do focus attention on the most critical aspect of any kind of training that involves a one-on-one relationship between a senior and junior colleague: the responsibility of the supervisor (mentor) for the scientific, intellectual and ethical development of the individual being supervised.

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3 Fraud in Biomedical Research, hearings before the Subcommittee on Investigations and Oversight of the House Committee on Science and Technology, 97th Congress (1981); see also Broad and Wade. Betrayors of the Truth, Ref. 3.
universities, while more critical of their performance in this area, tend to be more passive about the prospect of taking formal actions to improve that performance. Louis et al. comment that the data raise “some concerns about the degree to which research-intensive universities apparently rely almost exclusively on the more traditional interpersonal and personal models of values acquisition and social control.”

Perhaps it is time for change. As Jaroslav Pelikan has observed: “Alien though it may be to the sensibilities of an entire generation of scholars, the conclusion appears inescapable that the intellectual virtue of integrity in scholarly research—which like other articles of moral belief, may seem to be self-evident—is a principle that must be raised to the level of conscious attention and articulate formulation.”

(14) Research intensive universities—usually through faculty committees, graduate councils, faculty senates, or other similar bodies—have begun to develop statements of principles related to the wide variety of issues that face the modern research university. Some of these statements are responses to federal regulations in areas such as research involving human subjects or the use and care of laboratory animals. Some relate to university concerns about conflicts of interest or commitment, particularly in the growing relationship between universities and private industry. Some are responses to concerns often expressed by students and faculty in areas such as classified research or research on weapons. And finally, some are designed to express the university’s broad commitment to integrity in scholarship and the highest standards in the conduct of research.

Initially, academic institutions and scientific societies focused primarily on developing policies and procedures for responding to reports that scientific misconduct had occurred.(15) Gradually, attention shifted to the need for standards defining the proper conduct of research, in order to prevent the occurrence of misconduct. Yale University’s “Policy Statement on Collaborative Research,” published in 1982, pointed out that

it is hardly possible to exaggerate the damage that can result from such a breach of the academic commitment to truth. Academic fraud, if discovered, as it often is, not only shatters individual careers, but besmirches the entire cause of objective research, undermines the credibility of scholarship and renders the fragile tissues of confidence between scholar and scholar, teacher and student, the university and the public.(16).

Moreover, as the “Policy Statement” also noted:

In collaborative research the iniquity of academic fraud is compounded, for the perpetrator not only clouds his own academic future, but inevitably clouds that of his research colleagues—at a minimum, depriving them of the benefit of their own hard work, and at worst, staining their reputations in the view of outsiders who do not take the trouble to distinguish between those collaborators who are guilty and those who are in fact victimized.

The Yale policy then briefly addressed issues such as selection of collaborating scientists, adherence to the research protocol, inquiry as to the integrity of the processes for gathering and evaluating data, the responsibility of authors for the finished product, and the need to adapt general guidelines so that they are applicable to the practices and customs of different scientific fields, departments, and disciplines.

The Yale policy made clear what sanctions would be imposed for violation of the standards. Faculty found to have engaged personally in research fraud or to have agreed to publication of falsified or fraudulent data, generally would be dismissed from the university. If a faculty member’s involvement in research fraud results from failure to inquire about the data being collected or failure to comply with accepted research standards, the faculty member would be subject to censure or other appropriate action. Finally, if fraudulent work has been published, the university would announce the facts of the matter promptly, in sufficient detail and in such forums as necessary to inform the academic communities and to correct the public record.

The University of Michigan published a similar report in 1984: “Maintaining the Integrity of Scholarship.”(17) In that report, the university expounded on the ethical obligations of scholarship and the general procedures to be followed in conducting scholarly research. It warned of the pressures that can discourage integrity in scholarship” and provided advice on resisting such pressures.

The report offered suggestions for encouraging integrity in scholarship, such as including materials on ethical considerations in research in both undergraduate and graduate courses, encouraging discussion of ethical issues, clarifying and publishing accepted standards of behavior, and encouraging attention to ethical considerations in the laboratories. Finally, faculty were advised to set aside time to discuss with students such matters as data collection, drawing conclusions, giving citations, acknowledgements, and authorship.

The report also recommended steps that could be taken by university administrators:

• ensuring that guidelines for proper ethical conduct are clearly formulated, readily available, and openly discussed;
• encouraging efforts to raise ethical issues in the context of research;
• reminding scholars of their responsibility to help maintain high ethical standards;
• supporting committees charged with ensuring that research conforms to accepted guidelines;
• accepting the responsibility to undertake impartial investigations of allegations of unethical behavior.

The University of Michigan was among the first to suggest that pressures conducive to research fraud could be reduced by emphasizing quality rather than quantity of research as the basis for promotion, tenure, and similar decisions. Similarly, it was suggested that administrators avoid policies that put unreasonable burdens on scholars to obtain outside funding, and that they balance demands for research productivity with appropriate recognition of the importance of activities related to teaching and community service. Similar recommendations were directed to professional associations and funding agencies.

Harvard University Medical School published a series of policies in the wake of the Darsee affair. The first, published in January 1982, was reprinted in part in Science in 1982(18). Those guidelines were expanded and revised in
1988, and printed in the June issue of the Harvard Alumni Gazette. Entitled “Guidelines for Investigators in Scientific Research,”(11) they emphasize the importance of establishing standards for each laboratory, carefully supervising new investigators, and exercising caution in interpreting possibly ambiguous data.

Faculty are advised: (i) to ensure that each junior investigator is assigned to a specific faculty member in the research unit; (ii) to supervise the design of experiments and the process of acquiring, recording, examining, interpreting, and storing data; (iii) to hold regular, collegial discussions among all preceptors and trainees in the unit, “both to contribute to the scientific efforts of the members of the group and to provide informal peer review”; and (iv) to provide each new investigator (whether student, postdoctoral, fellow, or junior faculty) with applicable governmental and institutional requirements for the conduct of their research.

The guidelines emphasize the importance of establishing policies for the retention and storage of data and for providing responsible scientists with access to original results. Accordingly, faculty are urged to assure that custody of all original primary data be retained in the laboratory to be preserved “as long as there is any reasonable need to refer to them.” The chief of each unit is advised to decide whether the data may be disposed of after a specific number of years or if they should be preserved for the life of the unit. Guidance is also offered on recording experimental results (in bound books with numbered pages and an index to facilitate access).

The guidelines on authorship suggest that each coauthor verify the parts of a manuscript within his or her area of expertise, and that one author be designated as primary, with responsibility for the entire manuscript. Although each laboratory should establish its own rules, the guidelines state that the only reasonable criterion for authorship is to have made a significant intellectual or practical contribution to the research. In addition, the first author is responsible for assuring the laboratory chief or department head that he or she has reviewed all the to sign a statement indicating that they have reviewed and approved the final draft.

Finally, limits are recommended for the number of publications reviewed in making decisions about faculty appointments, promotion, and tenure. (For example, no more than five publications would be reviewed for appointment as assistant professor, seven for associate professor, and ten for full professor.) This emphasis on the quality rather than the quantity of one’s publications should remove some of the temptation to publish material prematurely. In any event, it is an approach more consistent with the objective of the appointment, promotion, and tenure processes, which is to evaluate an individual’s growth and development as a scholar.

CONCLUSION

Efforts to develop broad statements dealing with the policies and practices that define the university atmosphere for research and research training represent a new phase in the development of the research university. In part, this is a response to the enormous growth of the academic research enterprise and the concern that growth brings with it a certain loss of control, particularly in terms of the nature of the student-faculty interactions that are characteristic of good research training. In addition, attempts to formalize the principles of good research practice may be a response to a qualitative change in the university research atmosphere. Dorothy Nelkin, writing about science as intellectual property, suggests that “scientific knowledge has become, in effect, a commodity vulnerable to commercial interests, public demands, and military controls”(19). The pressure to produce results has become intense and the stakes, in terms of continued research support and access to information, have become much higher. Whether this pressure is distorting the values usually associated with the academic research community is the subject of much current debate. It does seem clear, however, that tensions exist that can interfere with the development of good scientists as well as with the conduct of good research.

Research training, through the process of doing research, has always involved the direct relationship between a learner and a teacher. Particularly at the highest levels, that is, for training for independent research, attempts to codify the nature of that relationship will fail if they impose uniformity in either principle or practice. And yet, independent and accepted precepts for doing science.

Universities, as the institutions responsible for the education of scientists, must assure that the independence of the scientist is in balance with the interdependence that characterizes science, and that an unambiguous and public commitment to the principles that define good research also applies to the training of those who do research.


References
(4) Ibid., p. 150.
(6) Ibid., p. 72.
(10) Op cit. (3).