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The scientific enterprise is built on a foundation of trust. Society toward graduate students, postdocs, and junior faculty in an academic setting, this guide is useful for scientists at all stages in their education and careers, including those working for industry and government. Thus, the term "scientist" in the title and the text applies very broadly and includes all researchers engaged in the pursuit of new knowledge through investigations that apply scientific methods.

In the past, beginning researchers learned the standards of science largely by participating in research and by observing other researchers make decisions about the interpretation of data and the presentation of results and interactions with their colleagues. They discussed professional practices with their peers, with support staff, and with more experienced researchers. They learned how the broad ethical values we honor in everyday life apply in the context of science. During that learning process, research advisers and mentors in particular can have a profound effect on the professional and personal development of beginning researchers, as is discussed in this guide. This assimilation of professional standards through experience remains vitally important.

However, many beginning researchers are not learning enough about the standards of science through research experiences. Science nowadays is so fast-paced and complex that experienced researchers to ensure that every researcher has a solid grounding in the professional codes of science. Though support for research has grown substantially in recent years, exciting opportunities have continued to multiply faster than resources, and the resulting disparity between opportunities and resources has further reduced the time available to researchers to discuss professional standards. As research has become more interdisciplinary and multinational, it has become more difficult to ensure that communication among the members of a research project is sufficient. Increased ties among academic, industrial, and governmental researchers have strengthened research but have also increased the potential for conflicts. And the rapid advance of technology—including digital communications technologies—has created a wealth of new capabilities and new challenges.

In this changing environment of the early 21st century, a short guide like thinking about the topics presented in this guide and by discussing those topics with their research groups and students. In this way, they help to maintain the foundations of the scientific enterprise and its reputation with society.

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The original was produced under the auspices of the National Academy of Sciences by the Committee on the Conduct of Science, which consisted of Robert McCormick Adams, Francisco Ayala (chair), Mary-Dell Chilton, Gerald Holton, David Hull, Kumar Patel, Frank Press, Michael Ruse, and Phillip Sharp.

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with procedures approved by the National Academies' Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by David Challoner, University of Florida. Appointed by the National Academies, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

For many graduate students, a seminar, class, or instructional module is their first formal exposure to responsible conduct in research. The guide explores the reasons for specific actions rather than stating definite conclusions about what should or should not be done in particular situations, and it can be used in formal sessions as well as for individual readings.

Scientific knowledge is achieved collectively through discussion and debate. Collective deliberation is an equally good way to explore how professional standards influence research. Group discussion can reveal the issues involved in a decision, connect those issues to more general standards, explore the interests and perspectives of different stakeholders, and identify possible strategies for resolving problems.

The guide hopes to stimulate group discussions, whether in orientations, seminars, research settings, or informal meetings.These discussions should include active researchers who bring their practical experience to the discussion and demonstrate by their presence that they recognize the critical importance of responsible conduct. The case studies included in this guide can be valuable to

CONTENTS

Climatologist Inez Fung's appreciation for the beauty of science brought her to the Massachusetts Institute of Technology where she received her doctoral degree in meteorology. "I used to think that clouds were just clouds," she says. "I never dreamed you could write equations to explain them—and I loved it."[1]

The rich satisfaction of understanding nature is one of the forces that keeps researchers rooted to their laboratory benches, climbing through the undergrowth of a sweltering jungle, or following the threads of a difficult theoretical problem. Observing or explaining something that no one has ever observed or explained before is a personal triumph that earns and deserves individual recognition. It also is a collective achievement, for in learning something new the discoverer both draws on and contributes to the body of knowledge held in common by all researchers.

Scientific research offers many satisfactions besides the exhilaration of discovery. Researchers seek to answer some of the most fundamental questions that humans can ask about nature. Their work can have a direct and immediate impact on the lives of people throughout the world. They are members of a community characterized by curiosity, cooperation, and intellectual rigor.

However, the rewards of science are not easily achieved. At the frontiers of research, new knowledge is elusive and hard won. Researchers often are subject to great personal and professional pressures. They must make difficult decisions about how to design investigations, how to present their results, and how to interact with colleagues. Failure to make the right decisions can waste time and resources, slow the advancement of knowledge, and even undermine professional and personal trust.

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[1]Skelton, R. . Washington, DC: Joseph Henry Press, 2005.

fundamental constituents of matter—new knowledge speaks to our sense of wonder and paves the way for future advances.

By considering all these obligations—toward other researchers, toward oneself, and toward the public—a researcher is more likely to make responsible choices. When beginning researchers are learning these obligations and standards of science, the advising and mentoring of more-experienced scientists is essential.

Terminology:
Values, Standards, and Practices

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All researchers have had advisers; many are fortunate to have acquired mentors as well. An adviser oversees the conduct of research, offering guidance and advice on matters connected to research. A mentor—who also may be an adviser—takes a personal as well as a professional interest in the development of a researcher. A mentor might suggest a productive research direction, offer encouragement during a difficult period, help a beginning researcher gain credit for work accomplished, arrange a meeting that leads to a job offer, and offer continuing advice throughout a researcher's career. Many successful researchers can point to mentors who helped them succeed.

Researchers in need of mentors have many options. Fellow researchers and research assistants, administrators, and support staff all can serve as mentors. Indeed, it is useful to build a diverse community of mentors, because no one mentor usually has the expertise, background, and time to satisfy all the needs of a mentee.

Mentors themselves can benefit greatly from the mentoring that they provide. Through mentoring others, researchers can be exposed to new ideas, build a strong research program and network of collaborators, and gain the friendship and respect of beginning researchers. Mentoring fosters a social cohesion in science that keeps the profession strong, and every researcher, at a variety of stages in his or her career, should act as a mentor to others.

Advisers and mentors often have considerable influence over the lives of beginning researchers, and they must be careful not to abuse their authority. The relationship between an adviser or mentor and an advisee or mentee can be complex, and conflicts can arise over the allocation of credit, publication practices, or the proper division of responsibilities. The main role of an adviser or mentor is to help a researcher move along a productive and successful career trajectory. By maintaining and modeling high standards of conduct, advisers and mentors gain the moral authority to demand the same of others.

A Change of Plans

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Beginning researchers also have responsibilities toward their advisers and mentors. They should develop clear expectations with advisers and mentors concerning availability and meeting times. Also, beginning researchers have a responsibility to seek out and work with mentors rather than expect that potential mentors will seek them out (though potential mentors often do take the initiative in establishing these relationships). Readily available guidelines that spell out the expectations of advisers, mentors, advisees, and mentees—whether provided through individual research groups or through research

Choosing a Research Group

institutions—can define the terms of these relationships. As with all relationships between humans, there can be no guarantee for compatibility, but both sides should act professionally, and institutions must promote good advising and mentoring by rewarding individuals who exhibit these skills and by offering training in how to become a better adviser or mentor.

In order to conduct research responsibly, graduate students need to understand how to treat data correctly. In 2002, the editors of the began to test the images in all accepted manuscripts to see if they had been altered in ways that violated the journal's guidelines. About a quarter of the papers had images that showed evidence of inappropriate manipulation. The editors requested the original data for these papers, compared the original data with the submitted images, and required that figures be remade to accord with the guidelines. In about 1 percent of the papers, the editors found evidence for what they termed "fraudulent manipulation" that affected conclusions drawn in the paper, resulting in the papers' rejection.

Researchers who manipulate their data in ways that deceive others, even if the manipulation seems insignificant at the time, are violating both the basic values and widely accepted professional standards of science. Researchers draw conclusions based on their observations of nature. If data are altered to present a case that is stronger than the data warrant, researchers fail to fulfill all three of the obligations described at the beginning of this guide. They mislead their colleagues and potentially impede progress in their field or research. They undermine their own authority and trustworthiness as researchers. And they introduce information into the scientific record that could cause harm to the broader society, as when the dangers of a medical treatment are understated.

This is particularly important in an age in which the Internet allows for an almost uncontrollably fast and extensive spread of information to an increasingly broad audience. Misleading or inaccurate data can thus have far-reaching and unpredictable consequences of a magnitude not known before the Internet and other modern communication technologies.

Misleading data can arise from poor experimental design or careless measurements as well as from improper manipulation. Over time, researchers have developed and have continually improved methods and tools designed to maintain the integrity of research. Some of these methods and tools are used within specific fields of research, such as statistical tests of significance, double-blind trials, and proper phrasing of questions on surveys. Others apply across all research fields, such as describing to others what one has done so that research data and results can be verified and extended.

Because of the critical importance of methods, scientific papers must include a description of the procedures used to produce the data, sufficient to permit reviewers and readers of a scientific paper to evaluate not only the validity of the data but also the reliability of the methods used to derive those data. If this information is not available, other researchers may be less likely to accept the data and the conclusions drawn from them. They also may be unable to reproduce accurately the conditions under which the data were derived.

The best methods will count for little if data are recorded incorrectly or haphazardly. The requirements for data collection differ among disciplines and research groups, but researchers have a fundamental obligation to create and maintain an accurate, accessible, and permanent record of what they have done in sufficient detail for others to check and replicate their work. Depending on the field, this obligation may require entering data into bound notebooks with sequentially numbered pages using permanent ink, using a computer application with secure data entry fields, identifying when and where work was done, and retaining data for specified lengths of time. In much industrial research and in some academic research, data notebooks need to be signed and dated by a witness on a daily basis.

Unfortunately, beginning researchers often receive little or no formal training in recording, analyzing, storing, or sharing data. Regularly scheduled meetings to discuss data issues and policies maintained by research groups and institutions can establish clear expectations and responsibilities.

The Selection of Data

All scientific research is susceptible to error. At the frontiers of knowledge, experimental techniques often are pushed to the limit, the signal can be difficult to separate from the noise, and even the question to be answered may not be well defined. In such an uncertain and fluid situation, identifying reliable data in a mass of confusing and sometimes contradictory observations can be extremely difficult.

Furthermore, researchers sometimes have to take risks to explore an innovative idea or observation. They may have to rely on a theoretical or experimental technique that is not fully developed, or they mfully fuully fuully fuully They may havurimhnique gJEjeSpas(urimhnique gJEjeSp

Changing Knowledge

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idea that peers will validate results, actual replication is selective. It is not practical (or necessary) to reconstruct all the observations and theoretical constructs made by others. To make progress, researchers must trust that previous investigators performed the work in accordance with accepted standards.

Some mistakes in the scientific record are quickly corrected by subsequent work. But mistakes that mislead subsequent researchers can waste large amounts of time and resources. When such a mistake appears in a journal article or book, it should be corrected in a note, erratum (for a production error), or corrigendum (for an author's error). Mistakes in other documents that are part of the scientific record—including research proposals, laboratory records, progress reports, abstracts, theses, and internal reports—should be corrected in a way that maintains the integrity of the original record and at the same time keeps other researchers from building on the erroneous results reported in the original.

Discovering an Error

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Some research behaviors are so at odds with the core principles of science that they are treated very harshly by the scientific community and by institutions that oversee research. Anyone who engages in these behaviors is putting his or her scientific career at risk and is threatening the overall reputation of science and the health and welfare of the intended beneficiaries of research.

Collectively these actions have come to be known as scientific misconduct. A statement developed by the U.S. Office of Science and Technology Policy, which has been adopted by most research-funding agencies, defines misconduct as “fabrication, falsification, or plagiarism in proposing, performing, or reviewing research, or in reporting research results.” According to the statement, the three elements of misconduct are defined as follows:

- Fabrication is “making up data or results.”
- Falsification is “manipulating research materials, equipment, or processes, or changing or omitting data or results such that the research is not accurately represented in the research record.”
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observing regulations governing research, failure to report misconduct, or retaliation against individuals who report misconduct to the list of behaviors that are considered misconduct. In addition, the National Science Foundation has retained a clause in its misconduct policies that includes behaviors that seriously deviate from commonly accepted research practices as possible misconduct.

A crucial distinction between falsification, fabrication, and plagiarism (sometimes called FFP) and error or negligence is the intent to deceive. When researchers intentionally deceive their colleagues by falsifying information, fabricating research results, or using others' words and ideas without giving credit, they are violating fundamental research standards and basic societal values. These actions are seen as

Fabrication in a Grant Proposal

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Is It Plagiarism?

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2. [illegible]

the worst violations of scientific standards because they undermine the trust on which science is based.

However, intent can be difficult to establish. For example, because trust in science depends so heavily on the assumption that the origin and content of scientific ideas will be treated with respect, plagiarism is taken very seriously in science, even though it does not introduce spurious results into research records in the same way that fabrication and falsification do. But someone who plagiarizes may insist it was a mistake, either in note taking or in writing, and that there was no intent to deceive. Similarly, someone accused of falsification may contend that errors resulted from honest mistakes or negligence.

Within the scientific community, the effects of misconduct—in terms of lost time, damaged reputations, and feelings of personal betrayal—can be devastating. Individuals, institutions, and even entire research fields can suffer grievous setbacks from instances of fabrication, falsification, and plagiarism. Acts of misconduct also can draw the attention of the media, policymakers, and the general public, with negative consequences for all of science and, ultimately, for the public at large.

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Science is largely a self-regulating community. Though government regulates some aspects of research, the research community is the source of most of the standards and practices to which researchers are expected to adhere. Self-regulation ensures that decisions about professional conduct will be made by experienced and qualified peers. But for self-regulation to work, researchers must be willing to alert others when they suspect that a colleague has violated professional standards or disciplinary practices.

To be sure, reporting that another researcher may have violated the standards of science is not easy. Anonymity is possible in some cases, but not always. Reprisals by the accused person and by skeptical colleagues have occurred in the past, although laws prevent institutions and individuals from retaliating against those who report concerns in good faith. Allegations of irresponsible behavior can have serious consequences for all parties concerned.

Despite these potential difficulties, someone who witnesses a colleague engaging in research misconduct has an unmistakable obligation to act. Research misconduct—particularly to fabrication, falsification, and plagiarism—has the potential to weaken the self-regulation of science, shake public confidence in the integrity of science, and forfeit the potential benefits of research. The scientific community, society, and the personal integrity of individuals all emerge stronger from efforts to uphold the fundamental values on which science is based.

All research institutions that receive federal funds must have policies and procedures in place to investigate and report research misconduct, and anyone who is aware of a potential act of misconduct must follow these policies and procedures. As noted in the previous section, institutions may define misconduct to include actions other than fabrication, falsification, and plagiarism; hence, the responses of institutions to allegations may vary.

Scientists and their institutions should act to discourage questionable research practices (QRPs) through a broad range of formal and informal methods in the research environment. They should also accept responsibility for determining which questionable research practices are serious enough to warrant institutional penalties. But the methods used by individual scientists and research institutions to address questionable research practices should be distinct from those for handling misconduct in science. In addition, different scientific fields may approach the task of defining QRPs in varying ways. For instance, in some fields the practice of salami publishing—deliberately dividing research results into the “least publishable units” to increase the count of one's publications—is seen as more questionable than in other fields.

The circumstances surrounding potential violations of scientific standards are so varied that it is impossible to lay out a checklist of what should be done. Suspicions are best raised in the form of questions rather than allegations. Expressing concern about a situation or asking for clarification generally works better than making charges. When questioning the actions of others, it is important to remain objective, fair, and unemotional. In some cases, it may be possible to talk with the person suspected of violating standards—perhaps the suspicion arose through a misunderstanding. But such discussions often are not possible or do not have a satisfactory outcome.

Another possibility is to discuss the situation with a good friend or trusted adviser. The possible consequences of this option need to be thoroughly considered in advance. Concerns about misconduct generally should be kept confidential, so a friend or adviser needs to be able to ensure confidentiality or to be honest about when confidentiality cannot be ensured. Sometimes the broad outlines of a case can be discussed without revealing details.

Responding to Suspected Violations

A Career in the Balance

Major federal agencies have instituted policies requiring that research institutions designate an official, usually called the research integrity officer, who is available to discuss situations involving suspected misconduct. Some institutions have several such designated officials so that complainants can go to a person with whom they feel comfortable.

Someone in a position to report a suspected violation of professional standards must clearly understand the standard in question and the evidence bearing on the case. He or she should think about the interests of everyone involved and ask what might be the possible responses of those individuals. It also is important to examine carefully one's own motivations and biases, since others inevitably will do so.

Institutional policies generally divide investigations of suspected misconduct into an initial inquiry to gather information and a formal investigation to reach conclusions and decide on responses. These procedures are designed to take into account fairness for the accused, protection for the accuser, and coordination with funding agencies. A model for this process can be seen in the guidelines set by the Department of Health and Human Services Office of Research Integrity.

Tests on Students

that involve some risk to themselves with no prospect of benefits? How should consent provisions be modified for children, prisoners, the mentally ill, the undereducated, or other vulnerable populations? Should the same provisions apply to all research conducted everywhere in the world, or should standards be modified to reflect local conditions? Formal training in bioethics is sometimes needed to analyze the complex moral issues raised by human participation in research, and various bodies, such as the President's Council on Bioethics in the United States, are continuing to study these issues. At a minimum, anyone who engages in research that involves humans must be aware of all relevant regulations and have appropriate training.

The use of animals in research and research training is also subject to regulations and professional codes. The federal Animal Welfare Act seeks "to insure that animals intended for use in research facilities . . . are provided humane care and treatment." The U.S. Public Health Service's

On Being a Scientist

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In the 17th century, many scientists kept new findings secret so that others could not claim the results as their own. Prominent figures of the time, including Isaac Newton, often avoided announcing their discoveries for fear that someone else would claim priority.

The solution to the problem of making new discoveries available to others while assuring their authors credit was worked out by Henry Oldenburg, the secretary of the Royal Society of London. He won over scientists by guaranteeing both rapid publication in the society's Philosophical Transactions and the official support of the society if the author's priority was questioned. Oldenburg also pioneered the practice of sending submitted manuscripts to experts who could judge their quality. Out of these arrangements emerged both the modern scientific journal and the practice of peer review.

Various publication practices, such as the standard scope of a manuscript and authorship criteria, vary from field to field, and digital technologies are creating new forms of publication. Nevertheless, publication in a peer-reviewed journal remains the most important way of disseminating a complete set of research results. The impor of others' ideas. This allows readers to locate the original source the author has used to justify a conclusion, and to find more detailed information about how earlier work was done and how the current work differs. Researchers also are expected to treat the information in a manuscript submitted to a journal to be considered for publication or a grant proposal submitted to an agency for funding as confidential.

Proper citation, too, is essential to the value of a reference. When

The Race to Publish

control mechanisms, they risk weakening conventions that have served science well. In particular, peer review offers a valuable way of evaluating and improving the quality of scientific papers. Methods of communication that do not incorporate peer review or a comparable vetting process could reduce the reliability of scientific information.

There are several reasons why researchers should refrain from making results public before those results have been peer reviewed. If a researcher publicizes a preliminary result that is later shown to be inaccurate or incorrect, considerable effort by researchers can be wasted and public trust in the scientific community can be undermined. If research results are made available to other researchers or to the public before publication in a journal, researchers need to use some kind of peer review process that may compensate for the lack of the formal journal process. Moreover, researchers should be cautious about posting anything (such as raw data or figures) to a publicly accessible Web site if they plan to publish the material in a peer-reviewed journal. Some journals consider disclosure of information on a website to be "prior publication," which could disqualify the investigator from subsequently publishing the data more formally.

Publication practices are susceptible to abuse. For example, researchers may be tempted to publish virtually the same research results in two different places, although most journals and professional societies explicitly prohibit this practice. They also may publish their results in "least publishable units"—papers that are just detailed enough to be published but do not give the full story of the research project described. These practices waste the resources and time of editors, reviewers, and readers and impose costs on the scientific enterprise. They also can be counterproductive if a researcher gains a reputation for publishing shoddy or incomplete work. Reflecting the importance of quality, some institutions and federal agencies have adopted policies that limit the number of papers that will be considered when an individual is evaluated for employment, promotion, or funding.

Restrictions on Peer Review and the Flow of Scientific Information

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When a paper is published, the list of authors indicates who has contributed to the work. Apportioning credit for work done as a team can be difficult, but the peer recognition generated by authorship is important in a scientific career and needs to be allocated appropriately.

Authorship conventions may differ greatly among disciplines and among research groups. In some disciplines the group leader's name is always last, while in others it is always first. In some scientific fields,

ceive much of the credit for the project even if the second researcher makes major contributions. Similarly, when an established researcher initiates a project, that individual may receive more credit than a beginning researcher who spends much of his or her time working on the project. When a beginning researcher makes an intellectual contribution to a project, that contribution deserves to be recognized, including when the work is undertaken independently of the labora-
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AUTHORSHIP AND

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challenging issues that arise when considering intellectual property. For example, to what extent should a researcher or an institution benefit from intellectual property? How should the rewards from intellectual property rights be shared among established researchers, beginning researchers, and research technicians? Can researchers take original data with them when they leave an institution? Generally, institutions own the data generated by a researcher, but contracts between researchers and their instititggmoo2( )52(i)2(n)2(d)2(yi./n)2(ggmoc(s)2(t)8l8

A Commercial Opportunity?

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Researchers have many interests, including personal, intellectual, financial, and professional interests. These interests often exist in tension; sometimes they clash. The term "conflict of interest" refers to situations where researchers have interests that could interfere with their professional judgment. Managing these situations is critical to maintaining the integrity of researchers and science as a whole.

Conflicting interests arise in many ways. A researcher who wants to start a company to commercialize research results generated in the laboratory might feel pressure to compromise the progress of students by having them work on company-related projects that are less related to their academic interests. A researcher might need to decide whether to publish a series of narrowly focused papers that would build the researcher's record of publication but not help the field progress as quickly as would a single paper containing the researcher's main conclusions. Or a researcher might have to decide whether to accept a grant to do routine work that will help the researcher financially but may not help the researcher's career or the careers of the students in the research group.

Conflicts of interest involving financial gain receive particular scrutiny in science. Researchers generally are entitled to benefit financially from their work—for example, by receiving royalties on inventions or bonuses from their employers. But in some cases the prospect of financial gain could affect the design of an investigation, the interpretation of data, or the presentation of results. Indeed, even the appearance of a financial conflict of interest can seriously harm a researcher's reputation as well as public perceptions of science.

Personal relationships may also create conflicts of interest. Some funding agencies require researchers to identify others who have been their supervisors, graduate students, or postdoctoral fellows, since these relationships are seen as having the potential to interfere with judgment about grants worthy of funding or papers worthy of publication. Similarly, though not formally acknowledged, romantic relationships can interfere with a researcher's judgment (and have the potential to lead to charges of sexual harassment and discrimination). For this reason, romantic relationships between professors and their advisees are generally unwise and are often prohibited by university policy.

Regulations and codes of conduct specify how some of these conflicts should be identified and managed. Funding agencies, research organizations, and many journals have policies that require researchers to identify their financial interests and personal relationships. Researchers should be aware of these policies and understand how they benefit science and their professional reputation. In some cases, the conflict cannot be allowed, and other ways must be found to carry out the research. Other financial conflicts of interest are managed through a formal review process in which potential conflicts are identified, disclosed, and discussed. However managed, timely and full disclosure of relevant information is important, since in some cases researchers joining a team or project may not be aware of a problem.

Conflicts of interest should be distinguished from conflicts of commitment. Researchers, particularly students, have to make difficult decisions about how to divide their time between research and other responsibilities, how to serve their scientific disciplines, how to respect their employer's interests, mission, and values, and how to represent science to the broader society. Conflicts between these commitments can be a source of considerable strain in a researcher's life and can cause problems in his or her career. Managing these responsibilities is challenging but different from managing conflicts of interest.

As in the case of conflicts of interest, many institutional policies offer some guidance on conflicts of commitment. For example, there are limits in many academic institutions regarding time spent on

A Conflict of Commitment

outside activities by faculty members. Training in laboratory management may offer valuable information on how to manage conflicts of commitment. As with conflicts of interest, identifying the conflict is an important first step in arriving at an acceptable solution.

Beyond conflicts of interest and commitment are issues related to the values and beliefs that researchers hold. Researchers can have strongly held convictions—for example, a desire to eliminate a particular disease, reduce environmental pollution, or demonstrate the biological underpinnings of human behavior. Or someone might have strong philosophical, religious, cultural, or political beliefs that could influence scientific judgments.

Strongly held values or beliefs can compromise a person's science in some instances. The history of science offers a number of episodes in which social or personal beliefs distorted the work of researchers. For example, the ideological rejection of Mendelian genetics in the Soviet Union beginning in the 1930s crippled Soviet biology for decades. The field of eugenics used the techniques of science to try to demonstrate the inferiority of particular human groups, according to nonscientific prejudices.

Despite such cautionary episodes, it is clear that all values cannot—and should not—be separated from science. The desire to do good work is a human value. So is the conviction that standards of honesty and objectivity must be maintained. However, values that compromise objectivity and introduce bias into research must be recognized and minimized. Researchers must remain open to new ideas and continually test their own and other's ideas against new information and observations. By subjecting scientific claims to the process of collective assessment, different perspectives are applied to the same body of observations and hypotheses, which helps minimize bias in research.

The standards of science extend beyond responsibilities that are internal to the scientific community. Researchers also have a responsibility to reflect on how their work and the knowledge they are generating might be used in the broader society.

Researchers assume different roles in public discussions of the potential uses of new knowledge. They often provide expert opinion or advice to government agencies, educational institutions, private companies, or other organizations. They can contribute to broad-based assessments of the benefits or risks of new knowledge and new technologies. They frequently educate students, policymakers, or members of the public about scientific or policy issues. They can lobby their elected representatives or participate in political rallies or protests.

In some of these capacities, researchers serve as experts, and their input deserves special consideration in the policy-making process. In other capacities, they are acting as citizens with a standing equal to that of others in the public arena.

Researchers have a professional obligation to perform research and present the results of that research as objectively and as accurately as possible. When they become advocates on an issue, they may be perceived by their colleagues and by members of the public as biased. But researchers also have the right to express their convictions and work for social change, and these activities need not undercut a rigorous commitment to objectivity in research.

The values on which science is based—including honesty, fairness, collegiality, and openness—serve as guides to action in everyday life as well as in research. These values have helped produce a scientific enterprise of unparalleled usefulness, productivity, and creativity. So long as these values are honored, science—and the society it serves—will prosper.

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The hypothetical scenarios included in this guide raise many different issues that can be discussed and debated. The following observations suggest just some of the topics that can be explored but are by no means exhaustive.

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Differences of opinion about when a dissertation is finished or almost finished are a common source of tension between Ph.D. students and their advisers. Good communication throughout the preparation of a dissertation is essential to avoid disappointment. Meetings should be held regularly to review progress and discuss future plans. If a student has difficulties discussing these issues with a thesis adviser, as Joseph did, the other members of a thesis committee should be willing to intervene to make sure that expectations are identified and made clear to all parties.

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Deborah and Kamala's principal obligation in writing up their results for publication is to describe what they have done and give the basis for their actions. Questions that they need to answer include: If they state in the paper that data have been rejected because of problems with the power supply, should the data points still be included in the published chart? How should they determine which points to keep and which to reject? What kind of error analyses should be done that both include and exclude the questionable data? How hard should they work to salvage these data given the difficulties with their measurements? Is the best course to focus on the systemic error (power fluctuations) and figure out how to eliminate the fluctuations or to repeat the experiment adjusting for the fluctuations? Consult-

modules might seem coercive to the students, and whether students who test the modules might have an unfair advantage over other students in the course. Explicit consent would be required if students might experience physical or psychological distress while using the modules, or if published information could be traced to individual students.

[illegible] 2)

Guidelines for the care and use of laboratory animals are designed to both protect the welfare of animals and enhance the quality of research. Both of these goals are being undermined by Hua's action, so who can they consult in the institution? What is the responsibility of the laboratory and its leadership for animal welfare?

[illegible] 32)

Contributions to a scientific field are not counted in terms of the number of papers. They are counted in terms of significant differences in how science is understood. With that in mind, Andre and his students need to consider how they are most likely to make a significant contribution to their field. One determinant of impact is the coherence and completeness of a paper. Andre and his students may need to begin writing before they can tell whether one or more papers are needed. Parts of the research can also be broken out for separate publication with a opportunity for different first authorship.

In retrospect, Andre and his students might also ask themselves

[illegible] ([illegible] 3)

Robert needs to know whether his company, the journal to which he plans to submit the paper, or his discipline has written policies pertaining to his situation. If so, he must decide whether to bring those policies to the attention of his supervisor, a research official in his company, or the editor of the journal; if not, he must decide whether to appeal to guidelines describing acceptable authorship practices in other documents. What are the possible outcomes of alternative actions that could help him make a decision?

[illegible] ([illegible] 2)

A software license is a legal contract, and all users must honor it, so Shen's first task is to correct his unauthorized distribution of the software. Once done, the commercialization decision can be made. Many researchers have found themselves in a position similar to the one Shen is in, and they have made different decisions. Some decide that they will continue to provide a free service to their research communities without seeking to commercialize a new idea or technique. Others decide that commercialization will best serve their communities, themselves, their institutions, or—with luck—all of the parties involved. As his adviser has suggested, Shen should work with the technology transfer officer at his university to learn more about his options.

[illegible]

Sandra has enrolled in the university to receive an education, not to work for industry. But working on industrially sponsored research is not necessarily incompatible with getting a good education. In fact, it can be a valuable way to gain insight into industrially oriented problems and to prepare for future work that has direct applications to societal needs. The question that must be asked is whether the nature of the research is compromising Sandra's education. Sandra's faculty adviser has entered into a relationship that could result in conflicts of interest. That relationship is therefore most likely to be subject to review by third parties. How can Sandra get help in resolving her own uncertainties? What would be the possible effects on her career if she did so?

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