ON BEING A SCIENTIST

A GUIDE TO RESPONSIBLE CONDUCT IN RESEARCH

THIRD EDITION

Committee on Science, Engineering, and Public Policy

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Preface

The scientific enterprise is built on a foundation of trust. Society trusts that scientific research results are an honest and accurate reflection of a researcher's work. Researchers equally trust that their colleagues have gathered data carefully, have used appropriate analytic and statistical techniques, have reported their results accurately, and have treated the work of other researchers with respect. When this trust is misplaced and the professional standards of science are violated, researchers are not just personally affronted—they feel that the base of their profession has been undermined. This would impact the relationship between science and society.

On Being a Scientist: A Guide to Responsible Conduct in Research presents an overview of the professional standards of science and explains why adherence to those standards is essential for continued scientific progress. In accordance with the previous editions published in 1989 and 1995, this guide provides an overview of professional standards in research. It further aims to highlight particular challenges the science community faces in the early 21st century. While directed primarily 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 often do not have the time or opportunity to explain why a decision was made or an action taken. Institutional, local, state, and federal guidelines can be overwhelming, confusing, and ambiguous. And beginning researchers do not always get the best advice from others or witness exemplary behavior. Anonymous surveys show that many researchers admit to engaging in irresponsible practices or have witnessed others doing so.[1]

Furthermore, changes within science have complicated efforts

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[1]Martinson, B.C., Anderson, M.S., and de Vries, R. "Scientists Behaving Badly." *Nature* 435(2005):737-738. Kirby, K., and Houle, F. A. Ethics and the Welfare of the Physics Profession. *Physics Today* 57 (11):42-49.

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 *On Being a Scientist* can provide only an introduction to the responsible conduct of research. Readers are thus encouraged to use the "Additional Resources" section of this guide, which lists many valuable publications, Web sites, and other materials on scientific ethics and professional standards, to find further material that explores this discourse. The challenges posed particularly by the increasing number of global and multinational ties within the science community will be further addressed in a subsequent publication of the National Research Council.

Established researchers have a special responsibility in upholding and promulgating high standards in science. They should serve as role models for their students and for fellow researchers, and they should exemplify responsible practices in their teaching and their conversations with others. They have a professional obligation to create positive research environments and to respond to concerns about irresponsible behaviors. Established researchers can themselves gain a new appreciation for the importance of professional standards by 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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President, National Academy of Sciences

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INTRODUCTION TO THE RESPONSIBLE CONDUCT OF RESEARCH

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. *Forecast Earth: The Story of Climate Scientist Inez Fung*. Washington, DC: Joseph Henry Press, 2005.

Over many centuries, researchers have developed professional standards designed to enhance the progress of science and to avoid or minimize the difficulties of research. Though these standards are rarely expressed in formal codes, they nevertheless establish widely accepted ways of doing research and interacting with others. Researchers expect that their colleagues will adhere to and promote these standards. Those who violate these standards will lose the respect of their peers and may even destroy their careers.

Researchers have three sets of obligations that motivate their adherence to professional standards. First, *researchers have an obligation to honor the trust that their colleagues place in them.* Science is a cumulative enterprise in which new research builds on previous results. If research results are inaccurate, other researchers will waste time and resources trying to replicate or extend those results. Irresponsible actions can impede an entire field of research or send it in a wrong direction, and progress in that field may slow. Imbedded in this trust is a responsibility of researchers to mentor the next generation who will build their work on the current research discoveries.

Second, *researchers have an obligation to themselves.* Irresponsible conduct in research can make it impossible to achieve a goal, whether that goal is earning a degree, renewing a grant, achieving tenure, or maintaining a reputation as a productive and honest researcher. Adhering to professional standards builds personal integrity in a research career.

Third, because scientific results greatly influence society, *researchers have an obligation to act in ways that serve the public*. Some scientific results directly affect the health and well-being of individuals, as in the case of clinical trials or toxicological studies. Science also is used by policy makers and voters to make informed decisions on such pressing issues as climate change, stem cell research, and the mitigation of natural hazards. Taxpayer dollars fund the grants that support much research. And even when scientific results have no immediate applications—as when research reveals new information about the universe or the 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**

Research is based on the same ethical values that apply in everyday life, including honesty, fairness, objectivity, openness, trustworthiness, and respect for others.

A "scientific standard" refers to the application of these values in the context of research. Examples are openness in sharing research materials, fairness in reviewing grant proposals, respect for one's colleagues and students, and honesty in reporting research results.

The most serious violations of standards have come to be known as "scientific misconduct." The U.S. government defines misconduct as "fabrication, falsification, or plagiarism (FFP) in proposing, performing, or reviewing research, or in reporting research results." 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.

Scientists who violate standards other than FFP are said to engage in "questionable research practices." 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.

Standards apply throughout the research enterprise, but "scientific practices" can vary among disciplines or laboratories. Understanding both the underlying standards and the differing practices in research is important to working successfully with others.

ADVISING AND MENTORING

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

Joseph came back from a brief summer vacation convinced that he would be able to finish up his Ph.D. in one more semester. Though he had not discussed the status of his thesis with his adviser or any other member of his thesis committee since the spring, he was sure they would agree that he could finish up quickly. In fact, he had already begun drawing up a list of companies to which he planned to apply for a research position.

However, when his research adviser heard about his plans, she immediately objected. She told him that the measurements he had made were not going to be enough to satisfy his dissertation committee. She said that he should plan to spend at least two more semesters on campus doing additional measurements and finishing his dissertation.

Joseph had always had a good working relationship with his adviser, and her advice had been very helpful in the past. Plus, he knew that he would need a good recommendation from her to get the jobs that he wanted. But he couldn't help but wonder if her advice this time might be self-serving, since her own research would benefit greatly from the additional set of measurements.

1. Should Joseph try to change his adviser's mind? For example, should he review what his measurements already show and compare that with what the new measurements would add and then ask his adviser to reconsider?
2. Should Joseph talk with other members of his thesis committee to get their opinions?
3. What actions could Joseph have taken earlier to avoid the problem?
4. What actions can Joseph take now to avoid future disappointment?

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

When a graduate student or postdoctoral fellow is deciding whether to join a research group, gathering information about the group and its leaders is valuable in helping that individual arrive at a good decision. Sometimes this information can be acquired from written materials, from conversations with current or previous students or postdoctoral fellows in the group, or by asking the senior researcher directly. This may help to determine whether you are really interested in the research that the group is or will be pursuing. Among the useful questions that could be asked are the following:[a]

- Who oversees the work of beginning researchers?
- Will a research adviser also serve as a mentor? If so, what is that person's mentoring style?
- What role does a trainee have in choosing and developing a project?
- How long do graduate students or postdoctoral fellows typically take to finish their training?
- What are the sources of funding for a project, and is the funding likely to be disrupted?
- Do beginning researchers participate in writing journal articles, and how are they recognized as authors?
- How much competition is there among group members and between the group and other groups?
- Are there potential dangers from chemical, biological, or radioactive agents? If so, what training is offered in these areas?
- What are the policies regarding ownership of intellectual property developed by the group?
- Are graduate students and postdoctoral fellows discouraged from continuing their projects when they leave?
- Are graduate students and postdoctoral fellows encouraged and funded to attend professional meetings and make presentations?
- Are there opportunities for other kinds of professional development, such as giving lectures, supervising others, or applying for funds?

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[a]For additional questions, please see: Committee on Science, Engineering, and Public Policy, Phillip A. Griffiths, Chair, *Adviser, Teacher, Role Model, Friend: On Being a Mentor to Students in Science and Engineering,* National Academy Press, 1997. 84 pp.

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.

THE TREATMENT OF DATA

In order to conduct research responsibly, graduate students need to understand how to treat data correctly. In 2002, the editors of the *Journal of Cell Biology* 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

Deborah, a third-year graduate student, and Kamala, a postdoctoral fellow, have made a series of measurements on a new experimental semiconductor material using an expensive neutron test at a national laboratory. When they return to their own laboratory and examine the data, a newly proposed mathematical explanation of the semiconductor's behavior predicts results indicated by a curve.

During the measurements at the national laboratory, Deborah and Kamala observed electrical power fluctuations that they could not control or predict were affecting their detector. They suspect the fluctuations affected some of their measurements, but they don't know which ones.

When Deborah and Kamala begin to write up their results to present at a lab meeting, which they know will be the first step in preparing a publication, Kamala suggests dropping two anomalous data points near the horizontal axis from the graph they are preparing. She says that due to their deviation from the theoretical curve, the low data points were obviously caused by the power fluctuations. Furthermore, the deviations were outside the expected error bars calculated for the remaining data points.

Deborah is concerned that dropping the two points could be seen as manipulating the data. She and Kamala could not be sure that any of their data points, if any, were affected by the power fluctuations. They also did not know if the theoretical prediction was valid. She wants to do a separate analysis that includes the points and discuss the issue in the lab meeting. But Kamala says that if they include the data points in their talk, others will think the issue important enough to discuss in a draft paper, which will make it harder to get the paper published. Instead, she and Deborah should use their professional judgment to drop the points now.

1. What factors should Kamala and Deborah take into account in deciding how to present the data from their experiment?
2. Should the new explanation predicting the results affect their deliberations?
3. Should a draft paper be prepared at this point?
4. If Deborah and Kamala can't agree on how the data should be presented, should one of them consider not being an author of the paper?

Most researchers are not required to share data with others as soon as the data are generated, although a few disciplines have adopted this standard to speed the pace of research. A period of confidentiality allows researchers to check the accuracy of their data and draw conclusions.

However, when a scientific paper or book is published, other researchers must have access to the data and research materials needed to support the conclusions stated in the publication if they are to verify and build on that research. Many research institutions, funding agencies, and scientific journals have policies that require the sharing of data and unique research materials. Given the expectation that data will be accessible, researchers who refuse to share the evidentiary basis behind their conclusions, or the materials needed to replicate published experiments, fail to maintain the standards of science.

In some cases, research data or materials may be too voluminous, unwieldy, or costly to share quickly and without expense. Nevertheless, researchers have a responsibility to devise ways to share their data and materials in the best ways possible. For example, centralized facilities or collaborative efforts can provide a cost-effective way of providing research materials or information from large databases. Examples include repositories established to maintain and distribute astronomical images, protein sequences, archaeological data, cell lines, reagents, and transgenic animals.

New issues in the treatment and sharing of data continue to arise as scientific disciplines evolve and new technologies appear. Some forms of data undergo extensive analysis before being recorded; consequently, sharing those data can require sharing the software and sometimes the hardware used to analyze them. Because digital technologies are rapidly changing, some data stored electronically may be inaccessible in a few years unless provisions are made to transport the data from one platform to another. New forms of publication are challenging traditional practices associated with publication and the evaluation of scholarly work.

MISTAKES AND NEGLIGENCE

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 may have to extend a conjecture into new realms. Such risk taking does not excuse sloppy research, but it should not be condemned as misguided.

Finally, all researchers are human. They do not have limitless working time or access to unlimited resources. Even the most responsible researcher can make an honest mistake in the design of an experiment, the calibration of instruments, the recording of data, the interpretation of results, or other aspects of research.

Despite these difficulties, researchers have an obligation to the public, to their profession, and to themselves to be as accurate and as careful as possible. Scientific disciplines have developed methods and practices designed to minimize the possibility of mistakes, and failing to observe these methods violates the standards of science. Every scientific result must be carefully prepared, submitted to the peer review process, and scrutinized even after publication.

Beyond honest errors are mistakes caused by negligence. Haste, carelessness, inattention—any of a number of faults can lead to work that does not meet scientific standards or the practices of a discipline. Researchers who are negligent are placing their reputation, the work of their colleagues, and the public's confidence in science at risk. Errors can do serious damage both within science and in the broader society that relies on scientific results. Though science is built on the

Changing Knowledge

In the early part of the 20th century, astronomers engaged in a prolonged debate over what were then known as spiral nebulae—diffuse pinwheels of light that powerful telescopes revealed to be common in the night sky. Some astronomers thought that these nebulae were spiral galaxies like the Milky Way at such great distances from the Earth that individual stars could not be distinguished. Others believed that they were clouds of gas within our own galaxy.

One astronomer who thought that spiral nebulae were within the Milky Way, Adriaan van Maanen of the Mount Wilson Observatory, sought to resolve the issue by comparing photographs of the nebulae taken several years apart. After making a series of painstaking measurements, van Maanen announced that he had found roughly consistent unwinding motions in the nebulae. The detection of such motions indicated that the spirals had to be within the Milky Way, since motions would be impossible to detect in distant objects.

Van Maanen's reputation caused many astronomers to accept a galactic location for the nebulae. A few years later, however, van Maanen's colleague Edwin Hubble, using a new 100-inch telescope at Mount Wilson, conclusively demonstrated that the nebulae were in fact distant galaxies; van Maanen's observations had to be wrong.

Studies of van Maanen's procedures have not revealed any intentional misrepresentation or sources of systematic error. Rather, he was working at the limits of observational accuracy, and his expectations influenced his measurements. Even cautious researchers sometimes admit, "If I hadn't believed it, I never would have seen it."

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

Two young faculty members—Marie, an epidemiologist in the medical school, and Yuan, a statistician in the mathematics department—have published two well-received papers about the spread of infections in populations. As Yuan is working on the simulation he has created to model infections, he realizes that a coding error has led to incorrect results that were published in the two papers. He sees, with great relief, that correcting the error does not change the average time it takes for an infection to spread. But the correct model exhibits greater uncertainty in its results, making predictions about the spread of an infection less definite.

When he discusses the problem with Marie, she argues against sending corrections to the journals where the two earlier articles were published. "Both papers will be seen as suspect if we do that, and the changes don't affect the main conclusions in the papers anyway," she says. Their next paper will contain results based on the corrected model, and Yuan can post the corrected model on his Web page.

1. What obligations do the authors owe their professional colleagues to correct the published record?
2. How should their decisions be affected by how the model is being used by others?
3. What other options exist beyond publishing a formal correction?

RESEARCH MISCONDUCT

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."
- Plagiarism is "the appropriation of another person's ideas, processes, results, or words without giving appropriate credit."

In addition, the federal statement says that to be considered research misconduct, actions must represent a "significant departure from accepted practices," must have been "committed intentionally, or knowingly, or recklessly," and must be "proven by a preponderance of evidence." According to the statement, "research misconduct does not include differences of opinion."

Some research institutions and research-funding agencies define scientific research misconduct more broadly. These institutional definitions may add, for example, abuse of confidentiality in peer review, failure to allocate credit appropriately in scientific publications, not

A Breach of Trust

Beginning in 1998, a series of remarkable papers attracted great attention within the condensed matter physics community. The papers, based largely on work done at Bell Laboratories, described methods that could create carbon-based materials with long-sought properties, including superconductivity and molecular-level switching. However, when other materials scientists sought to reproduce or extend the results, they were unsuccessful.

In 2001, several physicists inside and outside Bell Laboratories began to notice anomalies in some of the papers. Several contained figures that were very similar, even though they described different experimental systems. Some graphs seemed too smooth to describe real-life systems. Suspicion quickly fell on a young researcher named Jan Hendrik Schön, who had helped create the materials, had made the physical measurements on them, and was a coauthor on all the papers.

Bell Laboratories convened a committee of five outside researchers to examine the results published in 25 papers. Schön, who had conducted part of the work in the laboratory where he did his Ph.D. at the University of Konstanz in Germany, told the committee that the devices he had studied were no longer running or had been thrown away. He also said that he had deleted his primary electronic data files because he did not have room to store them on his old computer and that he kept no data notebooks while he was performing the work.

The committee did not accept Schön's explanations and eventually concluded that he had engaged in fabrication in at least 16 of the 25 papers. Schön was fired from Bell Laboratories and later left the United States. In a letter to the committee, he wrote that "I admit I made various mistakes in my scientific work, which I deeply regret." Yet he maintained that he "observed experimentally the various physical effects reported in these publications."

The committee concluded that Schön acted alone and that his 20 coauthors on the papers were not guilty of scientific misconduct. However, the committee also raised the issue of the responsibility coauthors have to oversee the work of their colleagues, while acknowledging that no consensus yet exists on the extent of this responsibility. The senior author on several of the papers, all of which were later retracted, wrote that he should have asked Schön for more detailed data and checked his work more carefully, but that he trusted Schön to do his work honestly. In response to the incident, Bell Laboratories instituted new policies for data retention and internal review of results before publication. It also developed a new research ethics statement for its employees.

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

Vijay, who has just finished his first year of graduate school, is applying to the National Science Foundation for a predoctoral fellowship. His work in a lab where he did a rotation project was later carried on successfully by others, and it appears that a manuscript will be prepared for publication by the end of the summer. However, the fellowship application deadline is June 1, and Vijay decides it would be advantageous to list a publication as "submitted" rather than "in progress." Without consulting the faculty member or other colleagues involved, Vijay makes up a title and author list for a "submitted" paper and cites it in his application.

After the application has been mailed, a lab member sees it and goes to the faculty member to ask about the "submitted" manuscript. Vijay admits to fabricating the submission of the paper but explains his actions by saying that he thought the practice was not uncommon in science. The faculty members in Vijay's department demand that he withdraw his grant proposal and dismiss him from the graduate program.

1. Do you think that researchers often exaggerate the publication status of their work in written materials?
2. Do you think the department acted too harshly in dismissing Vijay from the graduate program?
3. If Vijay later applied to a graduate program at another institution, does that institution have the right to know what happened?
4. What were Vijay's adviser's responsibilities in reviewing the application before it was submitted?

Is It Plagiarism?

Professor Lee is writing a proposal for a research grant, and the deadline for the proposal submission is two days from now. To complete the background section of the proposal, Lee copies a few isolated sentences of a journal paper written by another author. The copied sentences consist of brief, factual, one-sentence summaries of earlier articles closely related to the proposal, descriptions of basic concepts from textbooks, and definitions of standard mathematical notations. None of these ideas is due to the other author. Lee adds a one-sentence summary of the journal paper and cites it.

1. Does the copying of a few isolated sentences in this case constitute plagiarism?
2. By citing the journal paper, has Lee given proper credit to the other author?

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.

RESPONDING TO SUSPECTED VIOLATIONS OF PROFESSIONAL STANDARDS

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.

Treatment of Misconduct by a Journal

The emergence of embryonic stem cell cloning through somatic cell nuclear transfer as a "hot field" in the 1995–2005 period created pressures on all scientists to be first to achieve breakthroughs. The birth of Dolly the sheep at the Roslin Institute in Scotland in 1996 had a massive impact: the theoretical had happened and was visible. The race to clone other mammals, including humans, was seen by many as the potential capstone of a career.

In August 2005, a team at Seoul National University led by Hwang Woo-Suk reported in the pages of *Nature* the cloning of a dog, long considered to be much too complex to achieve, and Snuppy the dog became a symbol of the emergence of world-class stem cell research in Korea. The research team had been working in parallel on a project to create a stem cell line from a cloned human blastocyst, which was reported first in papers in *Science* in 2004 and 2005, stunning the scientific community worldwide.

Within weeks of the second paper appearing in print, skepticism arose about the claims made in the paper, particularly about the source and number of the oocytes used in the experiments. As an investigation looked into the research, more aspects unraveled, including the validity of the claimed data. By January 2006, the university's investigative team had determined that the papers were largely fraudulent, had to be withdrawn, and Hwang was prosecuted for the misuse of research funds. At *Science*, an editorial retraction was published: "Because the final report of the SNU investigation indicated that a significant amount of the data presented in both papers is fabricated, the editors of Science feel that an immediate and unconditional retraction of both papers is needed. We therefore retract these two papers and advise the scientific community that the results reported in them are deemed to be invalid."

From the point of view of scientists working in the field of stem cell biology, it was an enormous setback. The *Science* editorial made clear the waste of resources: "*Science* regrets the time that the peer reviewers and others spent evaluating these papers as well as the time and resources that the scientific community may have spent trying to replicate these results."[a] They effectively lost several years of work in assuming the validity of the published articles. The public's faith in the field was shaken, with consequences for the support of stem cell research that earlier existed. An independent review of the editorial procedures at *Science* provided insights into needed changes—new rules to ensure the authenticity of images, identification of the specific contribution of each author, undertaking a "risk assessment" on papers that might be more prone to fraud.

[a] Kennedy, D. "Editorial Retraction" *Science* 31 (2006):335.

A Career in the Balance

Peter was just months away from finishing his Ph.D. dissertation when he realized that something was seriously amiss with the work of a fellow graduate student, Jimmy. Peter was convinced that Jimmy was not actually making the measurements he claimed to be making. They shared the same lab, but Jimmy rarely seemed to be there. Sometimes Peter saw research materials thrown away unopened. The results Jimmy was turning in to their common thesis adviser seemed too clean to be real.

Peter knew that he would soon need to ask his thesis adviser for a letter of recommendation for faculty and postdoctoral positions. If he raised the issue with his adviser now, he was sure that it would affect the letter of recommendation. Jimmy was a favorite of his adviser, who had often helped Jimmy before when his project ran into problems. Yet Peter also knew that if he waited to raise the issue, the question would inevitably arise as to when he first suspected problems. Both Peter and his thesis adviser were using Jimmy's results in their own research. If Jimmy's data were inaccurate, they both needed to know as soon as possible.

1. What kind of evidence should Peter have to be able to go to his adviser?
2. Should Peter first try to talk with Jimmy, with his adviser, or with someone else entirely?
3. What other resources can Peter turn to for information that could help him decide what to do?

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.