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.

Ralph J. Cicerone
President, National Academy of Sciences

Charles M. Vest
President, National Academy of Engineering

Harvey V. Fineberg
President, Institute of Medicine

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.

[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.

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.

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.

HUMAN PARTICIPANTS AND ANIMAL SUBJECTS IN RESEARCH

Any scientist who conducts research with human participants needs to protect the interest of research subjects by complying with federal, state, and local regulations and with relevant codes established by professional groups. These provisions are designed to ensure that risks to human participants are minimized; that risks are reasonable given the expected benefits; that the participants or their authorized representatives provide informed consent; that the investigator has informed participants of key elements of the study protocol; and that the privacy of participants and the confidentiality of data are maintained.

U.S. federal regulations known as the Common Rule lay out requirements for research involving human participants. The Common Rule specifies which types of research fall under its jurisdiction, the provisions for obtaining informed consent, the procedures needed to gain approval of a project, and the training that researchers must undergo to use human participants in research. Federally funded research involving human participants also must be reviewed and approved by independent committees known as Institutional Review Boards (IRBs).[2] IRBs must approve all research covered by the Common Rule, must conduct regular reviews of such research, and must review and approve proposed changes in ongoing research. IRBs also have the authority to monitor informed consent procedures, gather information on adverse events, and examine conflicts of interest. These policies generally are observed for non-federally funded research as well and are followed in an increasing number of countries around the world.

The involvement of human participants in research can raise difficult questions. Should people be asked to participate in studies

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[2]While IRBs are independent, they are local review committees that fall under the jurisdiction of the funded research institution.

Tests on Students

For his dissertation project in psychology, Antonio is studying new approaches to strengthen memory. He can apply these techniques to create interactive Web-based instructional modules. He plans to test these modules with students in a general psychology course for which he is a teaching assistant. He expects that student volunteers who use the modules will subsequently perform better on examinations than other students. He hopes to publish the results in a conference proceedings on research in learning, because he plans to apply for an academic position after he completes the doctorate.

1. Should Antonio seek IRB approval for his research project with human participants?
2. What do students need to be told about Antonio's project? Do they need to give formal informed consent?

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 *Policy on the Humane Care and Use of Laboratory Ani-*

A Change of Protocol

Hua is doing a postdoctoral fellowship in a laboratory that studies cancer treatment. In the experiment she is overseeing, a cancer-prone strain of mice is allowed to develop visible tumors and then receives experimental drugs to observe the effects on the tumors.

Hua notices that the tumors are interfering with the ability of some of the mice to eat and drink. She also notices that some of the mice are weaker and more emaciated than the others, which she suspects is a consequence of their feeding difficulties. The protocol for the experiment states that the mice will be treated only if they exhibit obvious signs of pain or discomfort.

When she mentions her concerns to another postdoctoral fellow, he suggests not raising the issue with the rest of the lab. The mice will be euthanized as soon as the experiment is over, and their nutritional status probably has little or no effect on the drug treatment. Furthermore, if it proved necessary to change the experimental protocol, the previous work would be invalidated and the Institutional Animal Care and Use Committee would need to be notified.

1. What can Hua do to get more information about the issue?
2. If she decides to raise the issue with others, what is the best way to do so?
3. Should the original protocol have been approved?

mals, which applies to all animal research supported by the National Institutes of Health, requires institutions "to establish and maintain proper measures to ensure the appropriate care and use of all animals involved in research, research training, and biological testing." The policy requires adherence with both the Animal Welfare Act and the *Guide for the Care and Use of Laboratory Animals*, a document prepared and regularly updated by committees under the National Research Council. Guidance for researchers who use animals recommends that researchers carefully consider the "three R's" of animal testing alternatives: reduction in the numbers of animals used, refinement of techniques and procedures to reduce pain and distress, and replacement of conscious living higher animals with insentient material. Anyone who plans to use animals in research or teaching must be familiar with the relevant regulations and the guide and must receive appropriate training before beginning work.

The Animal Welfare Act and the *Policy on the Humane Care and Use of Laboratory Animals* both require institutions to have Institutional Animal Care and Use Committees (IACUCs), which include experts in the care of animals and members of the public. These committees review and approve research proposals using animals, oversee animal care programs and facilities, and respond to concerns about the use of animals in research. Also, private organizations like the American Association for the Accreditation of Laboratory Animal Care accredit research institutions using existing regulations and the guide as standards.

SHARING OF RESEARCH RESULTS

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 importance of publication accounts for the fact that the first to publish a view or finding—not the first to discover it—tends to get most of the credit for the discovery.

Once results are published, they can be freely used by other researchers to extend knowledge. But until the results are so widely known and familiar that they have become common knowledge, people who use them are obliged to recognize the discoverer by means of citations. In this way, researchers are rewarded by the recognition of their peers for making results public.

It may be tempting to adopt a useful idea from an article, manuscript, or even a casual conversation without giving credit to the originator of that idea. But researchers have an obligation to be scrupulously honest with themselves and with others regarding the use 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 analyzed carefully, many citation lists in published papers contain numerous errors. Beyond incorrect spellings, titles, years, and page numbers, citations may not be relevant to the current work or may not support the points made in the paper. Authors may try to inflate the importance of a new paper by including a reference to previously published work but failing to clearly discuss the connection between their new results and those reported in the previous study. Practices such as responsible peer review are thus important tools to prevent these problems.

Citations are important in interpreting the novelty and significance of a paper, and they must be prepared carefully. Researchers have a responsibility to search the literature thoroughly and to cite prior work accurately. Implied in this responsibility is that authors should strive to cite (and read) the original paper rather than (or in addition to) a more recent paper or review article that relies on the earlier article.

Researchers have other ways to disseminate research findings in addition to peer-reviewed research articles. Some of these, such as seminars, conference talks, abstracts, and posters represent long-standing traditions within science. Generally, these communications are seen as preliminary in nature, giving an author the chance to get feedback on work in progress before full publication in a peer-reviewed journal.

New communication technologies provide researchers with additional ways to distribute research results quickly and broadly. For example, raw data, computational models, the outputs of instruments,

The Race to Publish

By any standard, the field of organocatalysis is highly competitive. The rapid growth of new research approaches in the last decade, combined with the short time frame in which experiments can be carried out (days or hours), fueled a frantic race to publish results ahead of others in the field.

The case of Armando Cordova, a researcher at Stockholm University, brought the symptoms of that environment to light in a recent investigation by the university for research misconduct. The university determined that Dr. Cordova failed to cite other work properly and, instead, took credit for discoveries that were not his own; others in the field argue that the situation is more serious, more akin to fraud than ethical misconduct. As one news article noted, "They say Cordova steals research ideas at conferences and then presents the ideas as his own by publishing the results of hasty and often poorly executed parallel experiments."[a] In effect, he was able to appropriate others' ideas and get them into public view first by knowing of journals where he could publish more quickly.

As C&E News recounted the case, Cordova countered that his behavior was appropriate and that he simply practiced ethics that he learned from his mentors during graduate school and his early research career. In responding to the university investigation—which required him to attend an ethics course and submit all future papers to his dean for review before submission to journals—he acknowledged a need to cite others' work better, but he argued that there will be a continuing competition to publish first.

The university review has not ended the dispute. A continuing debate among organocatalysis researchers challenges the outcome and generates a broader discussion of the viability of community norms for ethical behavior in publication of experiments. Some conclude that the issues need to be addressed not just in the context of a specific university community. Rather, they argue that clearer international standards for acceptable competition among scientists in a given field are needed—not just for the sake of currently active scientists but also for the future practices of students trained in those laboratories. For science, the cost of such competitive publishing is more than individual careers; it tends to diminish the quality of published results. It also reduces collaboration, creates a reluctance to share research results, and generally undermines the trust that has enabled scientists to constructively build on one another's discoveries.

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[a]William G. Schulz, "Giving Proper Credit: Ethics Violations by a Chemist in Sweden Highlight Science's Unpreparedness to Deal with Misconduct" *Chemical and Engineering News* 85 (12):35-38.

simulation tools, records of deliberations, and draft papers all can be posted online and accessed by anyone before any of these results have undergone peer review.

To the extent that these new communication methods speed and broaden the dissemination and verification of results, they strengthen research. Science also benefits when more individuals have greater access to raw data for use in their own work. However, if these new ways of disseminating research results bypass traditional quality

Publication Practices

Andre, a young assistant professor, and two graduate students have been working on a series of related experiments for the past several years. Now it is time to write up the experiments for publication, but the students and Andre must first make an important decision. They could write a single paper with one first author that would describe the experiments in a comprehensive manner, or they could write two shorter, less-complete papers so that each student could be a first author.

Andre favors the first option, arguing that a single publication in a more visible journal would better suit all of their purposes. This alternative also would help Andre, who faces a tenure decision in two years. Andre's students, on the other hand, strongly suggest that two papers be prepared. They argue that one paper encompassing all the results would be too long and complex. They also say that a single paper might damage their career opportunities because they would not be able to point to a paper on which they were first authors.

1. How could Andre have anticipated this problem? And what sort of general guidelines could he have established for lab members?
2. If Andre's laboratory or institution has no official policies covering multiple authorship and multiple papers from a single study, how should this issue be resolved?
3. How could Andre and the students draw on practices within their discipline to resolve this dispute?
4. If the students feel that their concerns are not being addressed, to whom should they turn?
5. What kind of laboratory or institutional policies could keep disputes like this from occurring?
6. If a single paper is published, how can the authors make clear to review committees and funding agencies their various roles and the importance of the paper?

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

In some cases, scientific results cannot be freely disseminated because doing so might pose risks to commercial interests, national security, human health, or other objectives. For example, a company may choose not to publish internally conducted research that could give it an edge in the marketplace. Or a government or university-based laboratory may not be able to publish studies involving pathogens that could be used as biological weapons or mathematical results related to cryptography. These and similar restrictions on publications are controversial and (widely) debated.

Researchers working under such conditions may need to find alternate ways of exposing their work to professional scrutiny. For example, internal reviewers or properly structured visiting committees can examine proprietary or classified research while maintaining confidentiality.

The publication of results from fundamental scientific research has generally not been restricted in the United States unless those results are deemed so critical to national security that they are classified. The most recent episodes stem from the terrorist attacks of September 11th and the subsequent anthrax incidents in Washington in 2001. The U.S. government adopted or considered measures to restrict access to an expanded range of information or materials, to increase the monitoring of foreign students and researchers, and to screen some publications for "sensitive information." All of these steps reduce the traditional openness of scientific research and must continually be carefully weighed against the national security benefits they might produce.

AUTHORSHIP AND THE ALLOCATION OF CREDIT

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, research supervisors' names rarely appear on papers, while in others the head of a research group is an author on almost every paper associated with the group. Some research groups and journals simply list authors alphabetically.

Many journals and professional societies have published guidelines that lay out the conventions for authorship in particular disciplines. Frank and open discussion of how these guidelines apply within a particular research project—as early in the research process as possible—can reduce later difficulties. Sometimes decisions about authorship cannot be made at the beginning of a project. In such cases, continuing discussion of the allocation of credit generally is preferable to making such decisions at the end of a project.

Decisions about authorship can be especially difficult in interdisciplinary collaborations or multigroup projects. Collaborators from different groups or scientific disciplines should be familiar with the conventions in all the fields involved in the collaboration. The best practice is for authorship criteria to be written down and shared among all collaborators.

Several considerations must be weighed in determining the proper division of credit between investigators working on a project. If one researcher has defined and put a project into motion and a second researcher is invited to join in later, the first researcher may receive 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 laboratory's principal investigator. Established researchers are well aware of the importance of credit in science where traditions expect them to be generous in their allocation of credit to beginning researchers.

Sometimes a name is included in a list of authors even though that person had little or nothing to do with the content of a paper. Including "honorary," "guest," or "gift" authors dilutes the credit due the people who actually did the work, inflates the credentials of the added authors, and makes the proper attribution of credit more difficult. Journals, the administrators of research institutions, and researchers should all work to avoid this practice. Similarly, ghost authorship,

Who Gets Credit?

Robert has been working in a large engineering company for three years following his postdoctoral fellowship. Using computer simulations, he has developed a method to constrain the turbulent mixing that occurs near the walls of a tokomak fusion reactor. He has written a paper for *Physical Review* and has submitted it to the head of his research group for review. The head of the group says that the paper is fine but that, as the supervisor of the research, he needs to be included as an author of the paper. Yet Robert knows that his supervisor did not make any direct intellectual contribution to the paper.

1. How should Robert respond to his supervisor's demand to be an honorary author?
2. What ways might be possible to appeal the decision within the company?
3. What other resources exist that Robert can use in dealing with this issue?

where a person who writes a paper is not listed among the authors, misleads readers and also should be condemned.

Policies at most scientific journals state that a person should be listed as the author of a paper only if that person made a direct and substantial intellectual contribution to the design of the research, the interpretation of the data, or the drafting of the paper, although students will find that scientific fields and specific journals vary in their policies. Just providing the laboratory space for a project or furnishing a sample used in the research is not sufficient to be included as an author, though such contributions may be recognized in a footnote or in a separate acknowledgments section. The acknowledgments sections also can be used to thank others who contributed to the work reported by the paper.

The list of authors establishes accountability as well as credit. When a paper is found to contain errors, whether caused by mistakes or deceit, authors might wish to disavow responsibility, saying that they were not involved in the part of the paper containing the errors or that they had very little to do with the paper in general. However, an author who is willing to take credit for a paper must also bear responsibility for its errors or explain why he or she had no professional responsibility for the material in question.

The distribution of accountability can be especially difficult in interdisciplinary research. Authors from one discipline may say that they are not responsible for the accuracy of material provided by authors from another discipline. A contrasting view is that each author needs to be confident of the accuracy of everything in the paper—perhaps by having a trusted colleague read the parts of the paper outside one's own discipline. One obvious but often overlooked solution to this problem is to add a footnote accompanying the list of authors that apportions responsibility for different parts of the paper.

Who Should Get Credit for the Discovery of Pulsars?

A much-discussed example of the difficulties associated with allocating credit between beginning and established researchers was the 1967 discovery of pulsars by Jocelyn Bell, then a 24-year-old graduate student. Over the previous two years, Bell and several other students, under the supervision of Bell's thesis adviser, Anthony Hewish, had built a 4.5-acre radio telescope to investigate scintillating radio sources in the sky. After the telescope began functioning, Bell was in charge of operating it and analyzing its data under Hewish's direction. One day Bell noticed "a bit of scruff" on the data chart. She remembered seeing the same signal earlier, and by measuring the period of its recurrence, she determined that it had to be coming from an extraterrestrial source. Together Bell and Hewish analyzed the signal and found several similar examples elsewhere in the sky. After discarding the idea that the signals were coming from an extraterrestrial intelligence, Hewish, Bell, and three other people involved in the project published a paper announcing the discovery, which was given the name "pulsar" by a British science reporter.

Many argued that Bell should have shared the Nobel Prize awarded to Hewish for the discovery, saying that her recognition of the signal was the crucial act of discovery. Others, including Bell herself, said that she received adequate recognition in other ways and should not have been so lavishly rewarded for doing what a graduate student is expected to do in a project conceived and set up by others.

THE RESEARCHER IN SOCIETY

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.

Ending the Use of Agent Orange

In the early 1940s, a graduate student in botany at the University of Illinois named Arthur W. Galston found that application of a synthetic chemical could hasten the flowering of plants, enabling crops to be grown in colder climates. But if the chemical was applied at higher concentrations, it was extremely toxic, causing the leaves of the plants to fall off. Galston reported the results in his 1943 thesis before moving to the California Institute of Technology and then serving in the Navy during the final years of World War II.

Following the war, Galston learned that military researchers had read his thesis and had used it, along with other research, to devise powerful herbicides that could be used in wartime. Beginning in 1962, the U.S. military sprayed more than 50,000 tons of these herbicides on forests and fields in Vietnam. By far the most widely used mixture of defoliants was known as Agent Orange, from the orange stripe around the 55-gallon drums used to store the chemicals.

Galston later wrote that the use of his research in the development of Agent Orange "provided the scientific and emotional link that compelled my involvement in opposition to the massive spraying of these compounds during the Vietnam War." At the 1966 meeting of the American Society of Plant Physiologists, he circulated a resolution citing the possible toxic effects of defoliants on humans and animals and the long-term consequences for food production and the environment, which he sent to President Lyndon Johnson. During the next several years, as evidence for the toxic effects of Agent Orange accumulated, Galston and a growing number of other scientists continued to oppose the use of defoliants in the Vietnam War. In 1969, he and several other scientists met with President Richard Nixon's science adviser, whom Galston had known at Caltech, and presented him with information on the harmful effects of Agent Orange. The science adviser recommended to the president that the spraying be discontinued, and the use of defoliants was phased out in 1970, five years before the end of the war. Galton later wrote, "I used to think that one could avoid involvement in the anti-social consequences of science simply by not working on any project that might be turned to evil or destructive ends. I have learned that things are not that simple. . . . The only recourse is for a scientist to remain involved with it to the end."[a]

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National Institutes of Health, Ethics Program: *http://ethics.od.nih.gov.*

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