LABORATORY SAFETY IN RESEARCH

In addition to human participants and animal subjects in research, governmental regulations and professional guidelines cover other aspects of research, including the use of grant funds, the sharing of research results, the handling of hazardous materials, and laboratory safety.

These last two issues are sometimes overlooked in research, but no researcher or scientific discipline is immune from accidents. An estimated half million workers in the United States handle hazardous biological materials every day. A March 2006 explosion at the National Institute of Higher Learning in Chemistry in Mulhouse, France, killed a distinguished researcher and caused $130 million in damage.

Researchers should review information and procedures about safety issues at least once a year. A short checklist of subjects to cover includes:

- appropriate usage of protective equipment and clothing
- safe handling of materials in laboratories
- safe operation of equipment
- safe disposal of materials
- safety management and accountability
- hazard assessment processes
- safe transportation of materials between laboratories
- safe design of facilities
- emergency responses
- safety education of all personnel before entering the laboratory
- applicable government regulations

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.

[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.

INTELLECTUAL PROPERTY

Discoveries made through scientific research can have great value—to researchers in advancing knowledge, to governments in setting public policy, and to industry in developing new products. Researchers should be aware of this potential value and of the interest of their laboratories and institutions in it, know how to protect their own interests, and be familiar with the rules governing the fair and proper use of ideas.

In some cases, benefiting from a new idea may require establishing intellectual property rights through patents and copyrights, or by treating the idea as a trade secret. Intellectual property is a legal right to control the application of an idea in a specific context (through a patent) or to control the expression of an idea (through a copyright). Patent and copyright protections are legal mechanisms that seek to strike a balance between private gains and public benefits. They give researchers, nonprofit organizations, and companies the right to profit from a new idea. In return, the property owner must make the new idea public, which enables others to build on the idea.

A patent owner can protect his or her intellectual property rights by excluding others from making, using, or selling an invention so long as the patent owner provides a full description of how the invention is made, is used, and functions. Researchers doing patentable work may have special obligations to the sponsors of that work, such as having laboratory notebooks witnessed and disclosing an invention promptly to the patent official of the organization sponsoring the research. U.S. patent law provides clear criteria that define who is an inventor, and it is very important that all who have contributed substantially to an invention (and no one else) be included in a patent application.

Copyright issues are becoming more prominent as digital technologies have made copying and distributing information easier. Copyrights protect the expression or presentation of ideas, but they do not protect the ideas themselves. Thus, when a researcher writes an article or a book, a copyright (which may be transferred to the publisher) applies to the words and images in the publication, but others can use the ideas in that publication with proper attribution. Someone can make fair use of copyrighted material for nonprofit uses, such as research or education, but they cannot use the material in a way that would reduce its market value.

Industry often relies on trade secrets to maintain control over commercially valuable information generated through research. In this case, there is no requirement to make the idea public, though there is also no protection against the idea being developed independently at another research site. Legal action can be taken against someone who reveals a secret or against someone who obtains a secret illegally.

Most research institutions have policies that specify how intellectual property should be handled. These policies may specify how research data are collected and stored, how and when results can be published, how intellectual property rights can be transferred, how patentable inventions should be disclosed, and how royalties from patents are allocated. Also, patent law differs from country to country, and researchers need to take these differences into account when they are working on projects in other countries or in collaboration with researchers in other countries.

In some cases, the obligations of researchers who are doing potentially patentable work may delay the publication of scientific results. Thesis advisers and research supervisors need to make beginning researchers aware of this possibility, given the importance of publication in advancing their careers. Publication of researchers' work should not be delayed for unreasonable amounts of time to protect potentially patentable results. Decisions on whether to file a patent application should be made as quickly as possible. University technology transfer offices are a useful resource on these issues.

Institutional policies may or may not address some of the more challenging issues that arise when considering intellectual property. For example, to what extent should a researcher or an institution benefit from intellectual property? How should the rewards from intellectual property rights be shared among established researchers, beginning researchers, and research technicians? Can researchers take original data with them when they leave an institution? Generally, institutions own the data generated by a researcher, but contracts between researchers and their institutions typically specify the details of the arrangement, and researchers generally are entitled to a copy of the data they have generated. Furthermore, new laws, regulations, and policies continue to influence intellectual property rights, with important implications for researchers.

A Commercial Opportunity?

Shen was always interested in bioinformatics and decided to use some of his free time to write a program that others in his microbial genetics laboratory would find useful. Starting with a popular spreadsheet program on his university-provided computer, he wrote the program over the summer and posted it on his personal Web page as a bundle that combined the spreadsheet program and his own program. Over the next academic year, he improved his program several times based partly on the feedback he got from the people in his laboratory who were using it.

At national meetings, he discovered that researchers in other laboratories had begun to download and use his program package, and friends told him that they knew of researchers who were using it in industry. When the issue arose in a faculty meeting, Shen's faculty adviser told him that he should talk with the university's technology transfer office about commercializing it. "After all," his adviser said, "if you don't, a company will probably copy it and sell it and benefit from your hard work."

The director of the technology transfer office was much more concerned about another issue: the fact that Shen had been redistributing the spreadsheet in violation of its license. "You do have rights to what you created, but the company that sells this spreadsheet also has rights," he said. "We need to talk about this before we talk about commercialization."

1. What obligations does Shen have to the developer of the original spreadsheet program? To the university that provided the spreadsheet and computer?

2. What are the pros and cons of trying to commercialize a program that is based on another's product?

3. What conflicts and practical difficulties might Shen encounter if he tries to operate a business while working on his dissertation?

COMPETING INTERESTS, COMMITMENTS, AND VALUES

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

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

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

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

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

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

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

A Conflict of Commitment

Sandra was excited about being accepted as a graduate student in the laboratory of Dr. Frederick, a leading scholar in her field, and she embarked on her assigned research project eagerly. But after a few months she began to have misgivings. Though part of Dr. Frederick's work was supported by federal grants, the project on which she was working was totally supported by a grant from a single company. She had asked Dr. Frederick about this before coming to his lab, and he had assured her that he did not think that the company's support would conflict with her education. But the more Sandra worked on the project, the more it seemed skewed toward questions important to the company. For instance, there were so many experiments she needed to carry out for the company's research that she was unable to explore some of the interesting basic questions raised by her work or to develop her own ideas in other areas. Although she was learning a lot, she worried that her ability to publish her work would be limited and that she would not have a coherent dissertation. Also, she had heard from some of the other graduate students doing company-sponsored work that they had signed confidentiality statements agreeing not to discuss their work with others, which made it difficult to get advice. Dr. Frederick and the company's researchers were very excited about her results, but she wondered whether the situation was the best for her.

1. Has Dr. Frederick done anything wrong in giving Sandra this assignment?
2. What potential conflicts in terms of data collection, data interpretation, and publishing might Sandra encounter as she continues with her research?

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

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

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

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

Does the Source of Research Funding Influence Research Findings?

Information about sponsorship of academic research by tobacco companies over the last several decades has served to inform the scientific community about the issues to be considered in accepting funding from an interested party. The release of internal industry documents through a series of court cases has documented the deliberate effort to release experimental findings favorable to the companies.

Central to the story was the determination by the Environmental Protection Agency in 1993 that "environmental tobacco smoke" should be classified as a Class A carcinogen. Internal industry memoranda concluded that the possible banning of smoking in public places would reduce cigarette consumption and profits. In response to this shift in the regulatory environment, the tobacco industry created a nonprofit organization, the Center for Indoor Air Research, to fund well over 200 published studies to counter the EPA finding.[a] Additional steps included (1) formation of a consultant program funded by U.S., Japanese, and European tobacco companies to present favorable findings at scientific meetings and to publish findings; (2) introduction of bias into studies by misclassification of study subjects to reduce the apparent impact of secondhand smoke; and (3) placement of industry in-house scientists on journal editorial boards.[b]

This history of tobacco company funding does not mean that all industry-funded research is tainted. Companies, however, tend to fund external product studies that are likely to be favorable to them. This predisposition points toward the need for strong conflict of interest policies to minimize bias.

[a]Muggli, Monique E, Jean L. Forster, Richard D. Hurt, and James L. Repace. "The Smoke You Don't See: Uncovering Tobacco Industry Scientific Strategies Aimed against Environmental Tobacco Smoke Policies." *American Journal of Public Health* (September 2001); 91(9):1419-1423.

[b]Tong, Elisa K. and Stanton A. Glantz. "Tobacco Industry Efforts Undermining Evidence Linking Secondhand Smoke with Cardiovascular Disease." *Circulation* (2007); 116:1845-1854.

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]

[a]Galston, Arthur W. Science and Social Responsibility: A Case History. *Annals of the New York Academy of Science* (1972):196:223.