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Responsible Conduct in the Global Research Enterprise

A Policy Report

Responsible Conduct in the Global Research Enterprise

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- Launched in 1993
- Comprised of 105 academies
- Receives core funding from the Italian government
- Hosted by TWAS, the academy of sciences for the developing world
- Located in Trieste, Italy

IAP is a global network of the world's science academies, launched in 1993. Its primary goal is to help member academies work together to advise citizens and public officials on the scientific aspects of critical global issues.

IAP is particularly interested in assisting young and small academies achieve these goals and, through the communication links and networks created by IAP activities, all academies will be able to raise both their public profile among citizens and their influence among policy makers.

IAP Objectives are:

To position IAP as a recognized and independent provider of high-quality global science advice.
To initiate and support programs on capacity building, science education, and science communication.
To take a leading role in efforts to improve the effectiveness of international science cooperation.

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Responsible Conduct in the Global Research Enterprise

'All creatures seek happiness in whatever they do; but happiness cannot be had without righteous conduct. Therefore righteous conduct is obligatory for all.'

Physician Vāgbhaṭa in *Aṣṭāṅgahṛdaya*, believed to be sixth century AD,
as quoted in Valiathan (2009a).

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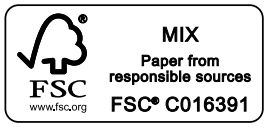

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Foreword

Forging an international consensus on responsible conduct in the global research enterprise.

A global research enterprise is emerging, with enormous benefit to economic and social well-being. Today throughout the world, millions more scientists and engineers are working than there were just two decades ago. Many countries are now investing substantial sums in scientific, engineering, medical, social science and other scholarly research. Multinational research teams are on the increase. In this new global context, shared scientific core values and norms are important for both the research community and the broader public. Yet significant differences among countries have been revealed in the definitions of and approaches to the conduct of responsible research.

These urgent issues are being addressed by the world's national scientific academies through their representative international organizations, the InterAcademy Council (IAC) and the IAP – the global network of science academies. This report, sponsored by IAC and IAP, represents the first joint effort by the scientific academies to provide clarity and advice in forging an international consensus on responsible conduct in the global research enterprise. It acknowledges and draws on information and recommendations from the many national and international organizations that have issued guidelines and statements on the basic responsibilities and obligations of researchers.

The report serves as a guide to basic values that govern the conduct of research and the communication of research results and recommends specific actions that should be used to ensure and maintain the integrity of research. We call attention to key recommendations in the report:

- Researchers have the primary responsibility for upholding standards of responsible conduct in research. They should employ the expected standards of their fields, observe applicable laws and regulations, be willing to share data with others, and agree on the standards to be observed in multidisciplinary collaborations.
- Research institutions need to establish clear, well-communicated rules that define irresponsible conduct and ensure that all researchers, research staff, and students are trained in the application of these rules to research. They should establish effective mechanisms for addressing allegations of research misconduct. Research institutions also need to create an environment that fosters research integrity through education, training, and mentoring and by embracing incentives that deter irresponsible actions.
- Public and private funding agencies should avoid policies that might lead to overemphasis of quantity over quality in the reward systems for researchers. They should provide support to researchers and research institutions at a level sufficient to ensure that research can be undertaken properly and responsibly, without compromising quality or integrity.
- Journals should use technological means to protect the integrity of the research literature. They should make retractions visible so that retracted papers are not used or cited. Both authors and journals should take steps to avoid duplicated publications that readers expect to be original and should refrain from citations designed only to boost the journal's impact factor.

As the report recommends, national scientific academies should provide forceful leadership on issues involving responsible conduct in research, including the establishment and dissemination of standards. They should work within their own scientific communities to ensure that effective mechanisms exist to address allegations of research misconduct. Interacademy organizations can play analogous roles at the regional and global levels.

We are grateful for the insightful work of the international authoring committee, ably co-chaired by Indira Nath and Ernst-Ludwig Winnacker. They and their committee colleagues have devoted much time and effort to the development of this report. We also appreciate the work of an independent set of experts who peer-reviewed the final draft of the report under IAC procedures. Financial support for this project is provided by IAP, IAC, and the U.S. National Research Council.

We recommend wide dissemination of this report to the scientific community; worldwide research-funding agencies; universities; governments, including ministries of education, research, science and technology; the private sector; scientific and professional societies and associations; relevant international scientific disciplinary unions; and other relevant international bodies. We trust that this report will contribute to international dialogue and action to promote and maintain the integrity of the global research enterprise.

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Preface

The contributions that scientific and scholarly research makes to economic growth, to improved health, and to addressing many other societal needs are widely appreciated around the world. As the Chinese Academy of Sciences has stated, "Science is a shared asset of humankind and serves its benefit" (CAS, 2007). Similarly, the Budapest World Science Forum (2011) notes that "more than ever before, the world will be shaped by science."

A truly global research enterprise is emerging. More researchers are working than ever before in human history, and more research is being performed. In addition, more researchers are crossing national borders to pursue education and careers, and a growing proportion of research involves international collaboration. This global research enterprise requires that the universal values of science be embodied in global standards of behavior that are understood and followed by all. Humanity needs new knowledge more than ever to solve its problems, and it has placed its trust in the research enterprise to generate this knowledge. To maintain this trust, everyone involved with the research enterprise must do what is necessary to ensure the integrity of research.

Responsible Conduct in the Global Research Enterprise is a straightforward, practical, and integrated guide to the responsible conduct of research. It reflects several major trends that have been reshaping the research enterprise.

- Research is changing as disciplines have forged connections and merged. New technologies are enabling researchers to pursue more data-intensive approaches. These developments have accelerated the generation of new knowledge while also raising issues in such areas as the allocation of credit, data sharing, and the interpretation and communication of results.
- As the amount of research funding and the number of researchers have risen around the world, research integrity has become a more visible issue. In response, a growing number of national and international organizations have issued policy statements on responsible research.
- The increased globalization of the research enterprise has raised a variety of research integrity issues, such as how to ensure that all the students and researchers in a collaborative project have shared values and have received common training.
- Research results increasingly underlie and influence public policy debates in many fields, including public health and medicine, climate and the environment, agriculture, and energy. The heightened role of research in public policy has led to greater scrutiny of research results and of the researchers and institutions that generate those results.

In response to these trends, a project to addresss issues of research integrity was launched in 2011 by the InterAcademy Council (IAC) and IAP – the global network of science academies. This report is the first product of that activity. It describes the basic values that govern the conduct of research and the communication of research results. It also contains principles and guidelines that individual researchers, students, research groups, universities and other research organizations, public and private research sponsors, journals, societies, policy makers,

academies, and other stakeholders should use to maintain the integrity of research. This report has been prepared by an expert committee on research integrity established by IAP and IAC, and it has been peer reviewed by an independent set of experts under IAC procedures. An expanded committee will extend this work by developing international educational materials on research integrity and scientific responsibility.

This report uses the words *science* and *research* very broadly. The guide posits that research encompasses many forms of disciplined human thought, including the natural sciences, the social sciences, and the humanities, along with the archives of that knowledge. These forms of knowledge and the methods used to arrive at this knowledge can be very different. Yet all researchers, whether in the sciences or in other forms of scholarship, are expected to adhere to the fundamental values that underlie good research.

Chapter 1 provides an introduction to the project and to the trends and issues that are part of the global context. Chapter 2 provides an overview of the core values of research and describes some of the other prerequisites needed for successful research. Chapter 3 examines the research process, from the origin of research ideas to the communication of research results, and identifies principles that need to be followed to protect research integrity. Chapter 4 compiles the recommendations made earlier in the report.

This report covers a wide range of issues that require a variety of responses from participants in the research enterprise. These issues include the need to ensure that mechanisms are in place to deal with egregious cases of irresponsible research behavior such as fabrication, falsification or plagiarism; the need to promote responsible practices and high standards throughout the research process; and the need for awareness of the broader social context for research. It acknowledges that some aspects of the conduct of research can differ among disciplines, countries, and cultures. The guide identifies principles where substantial international consensus exists or is within reach. It also suggests priority areas where efforts should be made to develop internationally applicable principles.

The ultimate goal of this project is to help the research enterprise develop an ethical framework that applies to every individual and institution involved in research. The committee responsible for this guide understands that this process is in its early stages. The IAC, IAP, other interacademy groups, individual academies, and academy members can and should play important roles in the development of this framework.

Because of the increasing importance of research in the broader society, scientists and other scholars bear a responsibility for how research is conducted and how the results of research are used. They cannot assume that they work in a domain isolated from the needs and concerns of the broader world. Similarly, they cannot assume that the proper conduct of research has relevance only for researchers. All researchers have an obligation to themselves, to their colleagues, and to the broader society to act in accord with the values and principles described in this guide.

Report review

This report was externally reviewed in draft form by six experts chosen for their diverse perspectives and technical knowledge, in accordance with procedures approved by the IAC Board. The purpose of this independent review was to provide candid and critical comments that would help the produce a sound report that meets the IAC standards for objectivity, evidence, and responsiveness to the study charge.

The review procedure and draft manuscript remain confidential to protect the integrity of the deliberative process. Although the reviewers provided constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations, nor did they see the final draft of the report before its release.

Reviewers of the report

The IAC and IAP thank the following individuals for their review of this report:

Burton MWAMILA, Vice Chancellor, The Nelson Mandela African Institute of Science and Technology, Arusha, Tanzania

Ken STRONGMAN, Professor Emeritus and Former Vice Chancellor, University of Canterbury, New Zealand

David VAUX, Deputy Director, The Walter and Eliza Hall Institute, Melbourne, Australia

Inder M. VERMA, American Cancer Society Professor of Molecular Biology, Salk Institute for Biological Studies, La Jolla, California, USA

Masayuki YAMAMOTO, Professor, Department of Biophysics and Biochemistry, University of Tokyo, Japan

LU Yongxiang, Past President, Chinese Academy of Sciences, Beijing, China

Monitor of the review process

A review monitor was responsible for ascertaining that the independent examination of this report was carried out in accordance with IAC procedures and that review comments were carefully considered.

The IAC and IAP thank the following for his participation as monitor in the review process:

Willem J.M. LEVELT, Former President, Royal Netherlands Academy of Arts and Sciences; Director Emeritus, Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands

1. Introduction

This policy report was prepared by a committee organized by the InterAcademy Council (IAC) and IAP – the global network of science academies. It sets forth values, principles, and guidelines for the responsible conduct of research that can serve as a common framework of good practices for the emerging global research enterprise. It makes broad recommendations specifying the responsibilities of various participants and stakeholders in that enterprise, and describes the institutional arrangements necessary to encourage and help ensure responsible conduct. The report also outlines ongoing changes in the research environment and the challenges to fostering research integrity. See Box 1-1 for the complete terms of reference.

Two key ideas and themes underlie the committee's analysis and recommendations. First, responsible conduct is an essential component of excellent research. Responsible conduct allows the self-correcting nature of research to operate effectively and accelerates the advance of knowledge. Second, while procedures and institutions to effectively investigate allegations of irresponsible research conduct and act on the results are necessary, efforts aimed at *preventing* irresponsible conduct and ensuring good practices through mentoring and education are ultimately more important. The committee hopes that this report encourages participants and stakeholders in the global research enterprise—researchers, research institutions, public and private research funders, journals, academies, and interacademy organizations—to redouble efforts to promote responsible research in the context of individual labs, institutions, disciplines, countries, regions, and the global enterprise.

The Globalization of Research

During the twentieth century, governments, businesses, and philanthropic organizations around the world recognized that new knowledge and new technologies can pay rich economic and social dividends. As a result, many countries greatly increased their investments in research and

BOX 1-1

Terms of Reference: Project on Research Integrity and Scientific Responsibility

Projects that address issues of research integrity and scientific responsibility will be undertaken by the InterAcademy Council (IAC) and IAP – the global network of science academies.

1. The IAC and IAP will jointly develop a short policy report on principles and guidelines, for individual scientists, educators, and institutional managers, on research integrity, which will include addressing issues of research management, reward, principles, practices, and culture. The product will have use throughout the global science community. In addition to constituting a basic source for use by all the IAP and other academies, it will be provided to research-funding agencies around the world; university leaders; ministries of education, research, science and technology; scientific and professional societies and associations; relevant international scientific disciplinary unions; and other relevant international bodies. This project will be undertaken by a committee of experts, appointed by the Co-Chairs of IAP and IAC. The draft report will be subjected to the IAC peer-review process involving an additional set of experts from around the world. This project should be completed by mid-2012.

2. The InterAcademy Council will develop international educational materials for individual scientists, educators, and institutional managers, addressing principles and guidelines for scientific responsibility, including scientific ethics, integrity, and responsibility for avoidance of misuse of science. The products will have use throughout the global science community. The project will be undertaken by an expanded IAP-IAC committee of experts and should be completed during 2013.

development (R&D). These investments have had a dramatic influence on human life. Science and technology have raised living standards, improved health, and augmented the ability of people to access information and communicate with each other. The relationship between investments in basic research and economic success is complex. But examples worldwide of science and technology-based industries—from Silicon Valley to Oxford to Bangalore to Beijing—demonstrate that a connection exists.

Many countries are now investing substantial sums in scientific and engineering research and development. Most industrialized countries are devoting between 1.5 percent and 3.5 percent of their gross domestic products to R&D, and many have pledged to increase these investments. Knowledge generated by research is a global asset available to anyone prepared to access that knowledge. An increasing number of countries have realized that their ability to take advantage of existing knowledge and generate additional knowledge requires increased investments in R&D (NSB, 2012).

Some of the fastest increases in R&D spending have been in rapidly developing countries that see science and technology as the foundation of prosperity. Millions more scientists and engineers are now working in these countries than there were just two decades ago. This great expansion of R&D has altered the global distribution of science and engineering work. In 1999, 38 percent of the world's R&D was performed in the United States, 27 percent in Europe, and 24 percent in Asia. In 2009, Asia accounted for 32 percent of world research, the United States for 31 percent, and Europe for 23 percent (NSB, 2012).

Research has become such a critical part of modern societies that protection of its core values and norms is important for both the research community and the broader society. Many national and international organizations have issued statements that describe the basic responsibilities and obligations of researchers. *Responsible Conduct in the Global Research Enterprise* draws on information from other statements in providing a guide for researchers, research administrators, and policy makers throughout the world.

The Changing Face of Science

The environment for research has been rapidly changing, with important implications for research integrity. For example, even as fields of research have become more fragmented and specialized, interdisciplinary research has become increasingly important and has contributed to major advances

(NAS-NAE-IOM, 2005). Examples include the application of information technology to problems in biology and the development of models to foresee the nature and consequences of climate change. Research funders and research institutions have created procedures and centers for bringing together people from different disciplines, but such collaborations still can encounter difficulties. For example, disciplines may have very different conventions for determining the order of authors listed on a publication. If these differences are not acknowledged and dealt with upfront, disagreements may surface later.

The increasing data-intensity of research in many fields also has implications for the conduct of research. Disciplines that have long relied on "big data," such as high-energy physics and astronomy, have established conventions for sharing and reusing data. Other fields, such as social and behavioral sciences research that uses online behavior data, may not have developed principles and guidelines for gathering, analyzing, storing, and sharing data.

A Growing Awareness of the Need to Maintain Research Integrity

Researchers and the research community traditionally have had the responsibility for defining and upholding ethical conduct in research (NAS-NAE-IOM, 1992). Researchers have used peer review and evaluation to judge the quality of research and to reward researchers. They have trusted that dishonest or substandard work would be uncovered through efforts to reproduce it. They have relied on the importance that researchers attach to maintaining their reputations as a strong disincentive to misbehavior.

The first formal laws and regulations to ensure responsible conduct in research addressed the protection of human research subjects and nonhuman laboratory animals.[1] Many countries have adopted such laws in reaction to widely publicized examples of wrongdoing, such as the human experiments undertaken by the Nazis, the Tuskegee syphilis study of the U.S. Public Health Service, and incidents of laboratory animal mistreatment (Adams and Larson, 2007; DHHS, 1993).

In recent decades, many universities and other research institutions, scientific societies, and national governments have developed rules, guidelines, institutions, and procedures to address actions that damage the

1 The imperative to maintain ethical behavior in clinical medical practice has been recognized since ancient times, as illustrated by Hippocratic Oath (Greece), the work of Sun Simiao (China), and the Oath of the Hindu Physician Caraca in the first century AD (India), (Chinaculture.org, 2012; NLM, 2012; Valiathan, 2009b).

research enterprise. As this body of work has developed, significant differences have emerged among countries (RIA, 2010). For example, the U.S. federal government defines "research misconduct" as "fabrication, falsification, or plagiarism (FFP) in proposing, performing, or reviewing research, or in reporting research results" (OSTP, 2000). By contrast, Finland defines "fabrication, misrepresentation, plagiarism and misappropriation" as "fraud in science," and includes behavior such as "understatement of other researchers' contribution to a publication and negligence in referring to earlier findings" as "misconduct in science" (TENK, 2002). The *Australian Code for the Responsible Conduct of Research* (NHMRC-ARC-UA, 2007) includes "failure to declare or manage a serious conflict of interest," "avoidable failure to follow research proposals as approved by a research ethics committee," and "willful concealment or facilitation of research misconduct by others" in its definition of research misconduct. Box 1-2 describes the terms used in this report.

Countries also differ in how allegations of irresponsible behavior in research are investigated and in the responses to findings. In most countries, the employer of a researcher accused of wrongdoing, such as a university or other research institution, holds the primary responsibility for investigation. In Japan, the Science Council of Japan developed a *Code of Conduct for Scientists*, and has asked research organizations to implement their own codes along with education programs for researchers (SCJ, 2006; RIKEN, 2006). In some countries, national funding agencies play an important role as an alternate mechanism for reporting allegations or as a mediator, such as the DFG Ombudsman established by Germany's national research funding agency (DFG, 1998). Some national bodies go farther, acting as overseers of institutional investigations or as enforcers of sanctions against those found guilty. In other countries, national bodies play only an advisory role. A perhaps unique approach has been taken by India, where the Society for Scientific Values was founded as a purely private, voluntary body that investigates allegations of misconduct and reports the results, but without legal or administrative authority (SSV, 2012). Discussions are ongoing in several countries over whether the systems currently in place should be modified (CCA, 2010; RIA, 2010; Godlee and Wager, 2012).

Several prominent organizations and conferences have focused attention on the responsible conduct of research. The 1st and 2nd World Conferences on Research Integrity (WCRI) were held in 2007 and 2010, respectively. The 2nd WCRI resulted in the *Singapore Statement on Research*

Integrity, a one-page statement defining responsible conduct in research. The Organization for Economic Cooperation and Development has held meetings and produced several reports aimed at defining good practices in promoting responsible research practices and addressing allegations of irresponsible behavior in international collaborations (OECD 2007, 2009). The European Science Foundation and the All European Academies also have worked to define best practices and have produced a code of research conduct (*The European Code of Conduct for Research Integrity*, ESF, 2010; ESF-ALLEA, 2011).

Going beyond issues of irresponsible research practices, the Budapest World Science Forum (2011) has put forward a vision of expanded world scientific cooperation. IAP (2005), along with other scientific organizations, has urged scientists to take responsibility for preventing misuse of biological agents.

The Incidence of Irresponsible Research Behavior

National organizations in several countries that deal with irresponsible research practices report on the number of investigations opened and how they were resolved. For example, in its 2010 annual report, the U.S. Office of Research Integrity reported that it closed 31 cases, with 9 findings of research misconduct under the U.S. government's definition (ORI, 2011). Also, recent research has sought to better understand the attitudes of researchers toward irresponsible research practices and their actual behavior (Fanelli, 2009; Tavare, 2012). These surveys tend to indicate that the incidence of irresponsible actions is higher than official statistics indicate.

Recent investigations have found that the number and percentage of scientific papers that are retracted has increased (Van Noorden, 2011). The problem of data irreproducibility is also attracting increasing attention; a significant percentage of published results may not be reproducible (Mullard, 2011). Retractions and data irreproducibility can result from a range of causes, including bias and misuse of statistical techniques, as well as intentional falsification and fabrication (Ioannidis, 2005).

Other things being equal, the incidence of irresponsible research practices will rise with the amount of research being undertaken and with the number of researchers. The number of researchers working in the world rose from 4 million in 1995 to 6 million in 2008, and worldwide R&D expenditures rose from $522 billion (current U.S. dollars) in 1996 to $1.3 trillion in 2009 (NSB, 2012). The committee does not believe that it is currently possible to generate an authoritative estimate of the incidence of

BOX 1-2
Terminology and Definitions

In developing this guide, the committee made several choices aimed at simplifying the language of the report and making it more useful.

In this report, all unethical and undesirable behaviors by researchers are referred to as *irresponsible research practices* or *irresponsible conduct*. The report refers to ethical and desirable behavior as *responsible research practices* or *responsible conduct*.

In many countries and contexts, those unethical practices that damage the research record, such as fabrication or falsification of data and plagiarism (FFP), are regarded as being egregious and receive significant sanctions.

Other behaviors, such as inappropriately requesting or conferring authorship, failure to appropriately share data, failure to retain data, inappropriate use of statistical or analytic methods, mistreatment of students and subordinates, publishing substantially the same work in multiple journals when readers expect the work to be original, and misrepresentation of research results in the media may not be considered as serious or sanctioned as heavily as FFP. Nevertheless, they are also considered irresponsible research practices in this report.

Finally, inappropriate treatment of human subjects of research, mistreatment of nonhuman laboratory animals, misuse of biological agents, and other behaviors that in most countries would be addressed under separate regulatory frameworks from FFP are also included as irresponsible research practices.

BOX 1-3
Notable Cases of Irresponsible Research Conduct

Hwang Woo-Suk (Korea), formerly of Seoul National University, was found to have fabricated results of research on human stem cells that was reported in *Science* in 2004 and 2005 (Kennedy, 2006).

Gopal Kundu (India), a biologist, was debarred from academy activities for 3 years by a committee of the Indian Academy of Sciences in 2010 after a finding that he had reused images in a 2005 paper that had been published earlier (Jayan, 2010). The 2005 paper was retracted by the journal that published it (SSV, 2007).

Li Liansheng (China), formerly of Xi'an Jiaotong University, was stripped of a national award by the Ministry of Science and Technology in 2010 after it found that some of his work was plagiarized (Jia and Tang, 2011).

Scott Reuben (United States), formerly a professor of anesthesiology and pain medicine at Tufts University, whose research had a major influence on pain management treatments, admitted to fabricating his clinical trials. He was sentenced to prison for health care fraud in 2010 (Edwards, 2010).

Jan Hendrik Schön (Germany), a physicist at Bell Laboratories, was found in 2002 to have falsified data underlying significant findings in semiconductor research (Bell Laboratories, 2002).

Diederik Stapel (the Netherlands), a social psychologist, admitted in 2011 that he fabricated and falsified data underlying numerous publications (Tilburg University, 2011).

Jon Sudbø (Norway) formerly a biologist at Oslo's Norwegian Radium Hospital, fabricated patient data for multiple studies published through 2005 on pain killers and smoking risk (Couzin and Schirber, 2006).

Irresponsible research conduct also occurs in the humanities. Examples from historical research and writing include S. Walter Poulshock's 1965 book *The Two Parties and the Tariff in the 1880s*, which was found to have been based on fabricated evidence; improper use of other authors' writings in the works of popular historians Stephen Ambrose and Doris Kearns Goodwin in the 1990s; and the fabrication of the "Hitler Diaries" in the 1980s (Lewis, 2004; MacArthur, 2008; Sternstein, 2002).

irresponsible research practices. However, even without such an estimate, the committee believes that the task it has undertaken is essential. Growth in the research enterprise, along with the continued emergence of high-profile cases in countries around the world (see Box 1-3), reinforce the need to address irresponsible research practices.

About the Study Process

The terms of reference for the study were developed and the committee was appointed during the third quarter of 2011 (Box 1-1). The committee Co-Chairs first met with staff in October. The full committee held face-to-face meetings in December 2011, January 2012, February 2012, and March 2012. In addition to its discussions and review of published materials, the committee consulted with several experts on issues of particular interest, including Melissa Anderson of the University of Minnesota, Philip Campbell of *Nature*, K.L. Chopra of the Society for Scientific Values, Judith Curry of the Georgia Institute of Technology, and Ryoji Noyori of RIKEN.

The committee has had access to a wealth of recent reports and background materials regarding research integrity. These documents demonstrate that significant differences exist among countries in policy frameworks for dealing with irresponsible research practices. Yet the committee strongly believes that global standards of behavior reflecting the universal values of science are not only possible but necessary. This report makes several broad policy recommendations that can be implemented universally, while recognizing that specific institutions, procedures, definitions, and sanctions used to address improper research behavior will vary by discipline and by country.

2. An Overview of Research Values

Responsible conduct in research is based on many of the same human values that apply in daily life, but these values have specific implications in the context of research.[2] The discussion in this guide draws on seven overlapping fundamental values:

- Honesty
- Fairness
- Objectivity
- Reliability
- Skepticism
- Accountability
- Openness

In research, being *honest* implies doing research and communicating about research results and their possible applications fully and without deception, whether of others or oneself.

Being *fair* means treating others with respect and consideration, whether in citing a colleague's ideas in a paper or mentoring a student in the proper conduct of research. In research—as in life—scientists and scholars should treat others as they hope and expect to be treated in return.

Objectivity implies that researchers try to look beyond their own preconceptions and biases to the empirical evidence that justifies conclusions. Researchers cannot totally eliminate the influence of their own perspectives from their work, but they can strive to be as objective as possible.

Research communities over many years have developed methods to enhance the *reliability* of the results they obtain, and researchers have an obligation to adhere to these methods or demonstrate that an alternative approach does not reduce the reliability of research results.

2 There are many discussions of scientific values that the committee drew on for this section, including CAS, 2007; CCA, 2010; ESF, 2010; GBAU, 2004; IAS, 2005; IOM-NRC, 2002; NAS-NAE-IOM, 2009; NHMRC-ARC-UA, 2007; and Steneck, 2007.

An allegiance to empirical evidence requires that researchers maintain a degree of *skepticism* toward research results and conclusions so that results and explanations are continually reexamined and improved.

Researchers are *accountable* to other researchers, to the broader society, and to nature. If challenged, they cannot appeal to authority but must demonstrate that their results or statements are reliable.

Finally, researchers need to be *open* with others for research to progress. All researchers deserve to work independently as they balance the competing considerations of "what if?" and "what if I am wrong?" But they ultimately need to convey to others their conclusions and the evidence and reasoning on which their conclusions are based so that those conclusions can be examined and extended. This requires careful storage of data and making data available to colleagues whenever possible.[3]

The primacy of these seven values explains why trust is a fundamental characteristic of the research enterprise. Researchers expect that their colleagues will act in accord with these values. When a researcher violates one of the values, that person's trustworthiness is diminished among other researchers. In addition, the public's trust in research can be damaged, with harmful effects on the entire research community.

Other Prerequisites for Research Excellence

Beyond the basic values that all researchers are expected to observe, the research enterprise has developed other procedures and principles that enhance the productivity of science and scholarship.

Successful research systems have ways of checking the integrity of results. The most obvious is replicating and building on previous results. If data or results reported by researchers to others are flawed, efforts to replicate or build on those data or results will be unsuccessful. Peer review, which is discussed at length in Chapter 3, is another way to bring a collective judgment of the research community to bear on the results of research.

Researchers have a responsibility to respect and care for the subjects of their research, whether those subjects are humans, laboratory animals, or some aspect of the physical environment that affects living organisms. Many research institutions and countries have created bodies to oversee research on particular subjects and ensure that researchers adhere to relevant laws and regulations.

3 In some situations and for certain types of data, sharing may be delayed, restricted, or prohibited. The specific practices and regulations will vary by country. Examples include information that identifies particular individuals, information that might be sensitive for national security reasons, and information related to patentable inventions.

Most results meet general expectations, but some lead in unexpected directions and can lead to the "creative destruction" of existing worldviews. Researchers should welcome rather than resist new results despite their disruptive potential. At the same time, they need to avoid unjustified claims of novel results. Successfully balancing the desire for novelty against the cumulative weight of past research is one measure of a good researcher.

Indigenous and traditional knowledge systems have much to contribute to research and should be respected for their potential contributions to human understanding and well-being. Researchers cannot assume that only one pathway leads to knowledge.

A successful research system embraces and encourages the contributions of groups that are underrepresented in particular fields, for example women, minority groups, and people with disabilities. Multiple perspectives can speed and broaden research, and the members of all groups can make vital contributions to human knowledge.

A successful research system draws on and contributes to a vigorous and effective system for higher education. Researchers have a responsibility to convey the methods and cumulative knowledge of research to the next generation. In particular, beginning researchers need guidance in absorbing and applying the ethical codes of research. Early-career researchers also need both independence and support to establish their careers while following their passions and interests.

Researchers need financial support to advance the frontiers of knowledge. Because the results of research can be difficult to predict, this financial support often must give researchers considerable latitude in deciding which questions to pursue and how to pursue them. Researchers need to be willing to disclose the sources of their support to avoid real or perceived conflicts of interest.

Valuable research is undertaken in a variety of settings: academic and non-profit institutions, industrial laboratories, and government organizations. Much of the research performed by commercial or government entities may not have publication as an end goal, but much of it does. The principles and guidelines in this report apply to all research that is performed with the aim of being reported publicly as part of the world's stock of available knowledge.

Finally, research systems that function effectively accord respect and recognition to those who perform research, both within the research enterprise and in the broader society. In the past, society has given great prestige to research and to researchers. Maintaining this respect requires that researchers act in accordance with the values of research.

3. Responsible Conduct in the Process of Research

The fundamental values discussed in Chapter 2 apply throughout the research process, from the development of a research plan to the reporting of results. However, their application in successive phases of research produces distinct principles that can guide the actions of researchers. This chapter describes those principles and their implications during the development of the research plan, the performance of research, the reporting of research results, and communicating with policy makers and the public. The final section of the chapter discusses the responsibilities of institutions in maintaining responsible conduct in research.

The Research Plan

Research ideas have many sources. Some emerge logically from the forward progress of a research program. Others are the product of long and careful individual thought about how to solve a problem. Many research ideas result from discussions among groups of people, each of whom brings a different background and perspective to a problem. Electronic communications can greatly increase the scope and pace of these discussions.

When research ideas are discussed in public, they become part of the collective knowledge of the research community. But fairness dictates that individual researchers be acknowledged for their contributions to science and scholarship. Also, researchers receive recognition for their contributions to the collective work of the research community, and this reward system is a powerful and useful motivating force in research. Appropriating the ideas of another person and using them without credit therefore undermines the social mechanisms of research.

In some cases, research ideas are discussed in private communications, such as grant proposals or meetings of a research group. These communications generally deserve to remain privileged as researchers work out the difficult problems associated with gaining reliable knowledge. In particular, the reviewers of grant applications are expected to maintain

confidentiality and avoid using ideas in those applications without permission in their own research and for their own gain.

Electronic communications can complicate the tasks of acknowledging individuals for their ideas and keeping privileged communications private. But new social mechanisms are emerging that can protect these important features of research. For example, the Creative Commons project allows the creators of intellectual work to disseminate their ideas while specifying how they expect to be credited for those ideas.

Recommendation

▶ Researchers have a responsibility to safeguard privileged information and to provide credit when using others' ideas.

The Review of Research Proposals

Peer review of research reports submitted for publication is described later in this chapter under "Reporting Research Results." But peer review is also used to judge proposals for research funding. In this form of peer review, experts in a field of research make judgments that influence the allocation of scarce resources, whether funding, prizes, employment, promotion, or the use of equipment or facilities. In a related form of review known as merit review, a group with a broader range of expertise judges both the value of proposed research within a field of science or scholarship and other qualities such as economic effects, practical applications, social relevance, or policy relevance. Review of research proposals is an essential component of the research enterprise and a basic obligation of researchers.

Since the future course of research cannot be fully predicted, any review process is fallible. Also, review tends to be a conservative process. Studies of peer review of proposals and publications have shown tendencies toward bias in the process (Budden, et. al., 2008; Campanario, 2009; Johnson, 2008). Innovative and interdisciplinary research, and research performed at less prestigious research institutes, by less established researchers, or by minority researchers (including women in fields where they are underrepresented), may be undervalued by reviewers. Also, reviewers have justifiable differences in perspective over the merit of proposals. It is easier to identify poor proposals than it is to distinguish between strong proposals. It may be difficult to determine which proposals

will lead to excellent but nonrevolutionary research and which to excellent revolutionary research. Reliability may improve when reviewers use specific, well-defined measures and multiple dimensions of quality in place of, or in addition to, general or global assessments that rate the entire proposal on a five-point or nine-point scale.[4] Alternatives to the peer review of proposals exist, such as funding investigators rather than projects or allowing program managers to allocate funding. However, these and other alternatives can end up funding projects of lower overall quality. Though the peer-review system for research proposals has shortcomings, it compares favorably with the available alternatives.

Peer reviewers seek to assess the potential of a proposed project to produce new knowledge, but research proposals and the review process often undervalue a critical characteristic of proposed research—the uncertainties that are likely to accompany the knowledge that will be generated. Investigators need to be honest about both the potential benefits and inevitable limits of their proposed research. When this information is not included in a research proposal, funders and reviewers should make an effort to obtain it. A more complete picture of the research to be done leads to better funding decisions and to more realistic expectations of the value of research results.

Different research funders have different ways of reviewing research proposals. Agencies and philanthropies may convene groups of experts who meet as a committee to review proposals and make collective decisions. Others send proposals to individual reviewers in much the same way that research articles are reviewed. International agencies tend to have experts from different countries to overcome local differences and also to understand different aspects of the proposal. In some countries, the groups qualified to review a proposal may be small or negligible for a particular discipline. Even in larger countries, recruiting expert reviewers can be difficult, given the increase in the number of proposals to be reviewed. Thus, international reviewers may add value even in national evaluations.

As interdisciplinary research becomes more common, review procedures are changing to accommodate proposals that range beyond the expertise of any one individual. Funders supporting interdisciplinary research often call on reviewers from different disciplines so that the group as a whole has a working knowledge of the disciplines encompassed

4 For example, reviewers of proposals to the U.S. National Institutes of Health provide ratings on five core review criteria in addition to an overall impact score (NIH, 2008).

in the proposal. Some funders review interdisciplinary research in the same way as disciplinary research by using a small number of review panels, each of which covers several research fields.

Irresponsible practices can occur among both the researchers submitting research proposals and among reviewers. Some investigators may send duplicate proposals to different funders without notifying them, thereby straining the resources available for reviewing. Or investigators may give too little credit to work done by others, even plagiarize, in a misguided effort to boost their own credentials. Researchers may not have observed regulatory norms in such areas as research involving humans, animals, or the environment. One way to minimize such lapses would be to have investigators certify to their institutions and to funding agencies that their proposals adhere to established standards of responsible conduct.

Reviewers have been known to appropriate ideas from research proposals. Another fear is that reviewers who are research competitors will delay a proposal while hastening their own investigations. Reviewers should disclose any potential conflicts of interest to funders, and should withdraw if the conflict could bias their judgment.

Researchers who submit proposals often complain of poor assessments, substandard evaluations, or reviewers who do not understand the proposals. The feedback from reviewers is not always specific or useful. Reviewers of proposals are typically anonymous to ensure frank and critical judgments, but anonymity can protect poor reviewers.

Reviewers and review mechanisms need to be fair and accountable. An appeal mechanism could allow investigators to submit a proposal to further review. Investigators could be instructed in how to make proposals stronger. Review mechanisms can be altered so that they are less conservative and subjective—for example, by instructing reviewers to flag particularly innovative proposals for a supplementary review process.

Recommendation

- Researchers have a responsibility to participate in the review of research proposals and not to abuse the trust on which the review process is based. They should disclose conflicts of interest and treat colleagues fairly in reviewing their ideas. Research sponsors should use international reviewers where feasible.

Social Responsibility in Research Plans

The choice of research plans also entails issues of social responsibility. Science and other forms of scholarship have been incredibly productive by seeking knowledge unfettered by tradition, ideology, and external pressure. At the same time, research can have a profound influence on the environment, human health and well-being, economic development, national security, and many other facets of human life. Many areas of science and technology can be used for destructive as well as constructive purposes, and researchers have a special responsibility to understand and address issues of "dual use." Research on biological pathogens, for example, poses both risks and benefits for human health (see Box 3-1). These issues and the international implications have been grappled with by the IAP – the global network of science academies (IAP, 2005).

Research cannot be justified if it inflicts unacceptable harm on the object of research, whether people, animals, society, the environment, or human cultures, where "acceptability" is a social judgment that weighs potential gains against potential harms. Research also is unacceptable if it conflicts with the basic human values of autonomy, freedom, dignity, nondiscrimination, and a lack of exploitation. National or international laws or conventions can limit research. Some research also can be described only as injurious to human welfare, such as research on biological weapons or torture, and societies are justified in prohibiting research of this type.

The constraints imposed on research by social considerations vary from one place and time to another. Thus, research using embryonic stem cells is not acceptable in some countries and is permitted in others. Research involving recombinant DNA roused great passions in the 1970s, but is now widely practiced. Some countries do not allow certain kinds of genetic studies or research on human stem cells. Drug trials are an area of concern in some countries where subjects may not be aware of risks and may succumb to unfair practices because of lax monitoring.

Researchers have learned that they cannot dissociate themselves from the uses of the new knowledge they generate. They need to take into consideration the reasonably foreseeable consequences of their own activities. They also have an obligation to participate in the social mechanisms, both within the research community and in the broader society, that explore the implications of research and impose constraints on research if those constraints are justified.

BOX 3-1
The H5N1 Controversy

The recent controversy over studies of the H5N1 flu virus illustrates the tension between unfettered research and the possible social implications of that research (*Science*, 2012).

In 2011, two groups of virologists led by Ron Fouchier of Erasmus Medical Center in Rotterdam and Yoshihiro Kawaoka of the University of Tokyo and the University of Wisconsin-Madison, submitted papers for publication reporting on their work to genetically alter H5N1 so that it would be more transmissible between mammals. The papers raised concerns that the altered viruses themselves or the methodologies being reported could be misused to create a global flu pandemic. The journal editors passed the papers to a U.S. government advisory body, the National Science Advisory Board for Biotechnology (NSABB), which provides advice on the publication of dual-use methodologies and results.

In late 2011, NSABB called for the researchers to redact portions of their papers. This set off an intense debate in the global research community and the broader public over the extent to which publication of such research should be restricted, and whether a body of a single national government should have such a prominent role in making those decisions. At the same time, the researchers themselves asked NSABB to reconsider the decision, arguing that publication of the full results would make a significant contribution to global public health. The authors also clarified their original work, assuaging some of the earlier concerns. In March 2011, NSABB reversed its earlier decision, and both papers were subsequently published. This followed a recommendation by a meeting organized by the World Health Organization that the papers be published (Butler, 2012).

Recommendation

▶ Researchers should bear in mind the possible consequences of their work, including harmful consequences, in planning research projects.

Carrying Out Research

The methods used to gain knowledge in science and scholarship are as varied as the subjects of research. Some research programs are almost purely theoretical, while others draw on empirical data with few theoretical preconceptions. Complex instruments, including computers, are used to gather and analyze data in many fields; for example, astronomers now post petabytes of new data online each week for all to read almost as soon as those data are gathered. Some fields are closely related to human concerns or commercial applications, while others are seemingly distant from these issues.

Over time, individual fields of research have developed expectations about the methods to be used in that field. Some of these expectations are universally shared; others are specific to individual fields of research. For example, some fields have particular requirements for documenting, dating, witnessing, and archiving research results.

In most countries, laws and regulations govern particular aspects of research, such as the treatment of human subjects and laboratory animals or the use of research funds, and violation of these provisions can subject a researcher to legal sanctions. In addition, the research community in general, and in particular research disciplines, has other expectations that are related to the fundamental values underlying research. All researchers are expected to keep clear, accurate, and secure records of their research data and corresponding primary material so that the work can be verified or replicated by others. They also are expected to share their data with others, including, where feasible, the research materials and software that enables them to draw their conclusions. Providing access to data, algorithms, and software is especially important in areas of research where results cannot be duplicated, such as research on natural phenomena and simulations. Researchers who fail to meet these expectations place their reputations at risk.[5]

5 For a recent treatment of issues related to research data, see the Royal Society report *Science as an open enterprise* (2012).

As the previous paragraph suggests, it may not always be possible or feasible to replicate all observations or share all data. Researchers are entitled to establish priority or ownership claims before disseminating their results. Sensitive data regarding human subjects may need to be anonymized. In these cases, researchers should be prepared to explain why data are not being released, and journals may require the provision of such explanations as a condition of publication. Also, researchers may need to seek other ways of submitting their results to the judgment of peers if data cannot be publicly released.

Exploring what is unknown in research can be as important as exploring what is known. Researchers have a responsibility to identify different types of uncertainty, ambiguity, and ignorance in their conclusions, especially in areas where research results inform policy. Wherever possible, they should have their models independently validated, should make information on data quality available, and should test for flaws in reasoning. Such steps increase the trust of the public in the results of research and make that research more reliable.

In some fields, policies and expectations related to data sharing are changing rapidly. For example, the ability to sequence the human genome at rapidly decreasing cost is raising a host of ethical issues about the management and sharing of genetic information. How should genetic information be handled, stored, and provided to research subjects? For such information to be used for clinical diagnoses, strict regulations and certified protocols for handling DNA samples may be necessary. Research fields need to have mechanisms to examine these issues and arrive at collective judgments about how best to handle them.

In addition, new methods of communicating data and research results are raising new issues for the performance of research and the sharing of research data. Researchers can now post large databases online, widely disseminate research results online, and participate in widely available public forums outside the traditional peer-reviewed literature. Research fields may need to develop new methods of reviewing results and arriving at consensus to deal with such changes.

Differences in research methods can create complications in multidisciplinary collaborations. Different fields can have different ways of gaining and analyzing information, drawing conclusions, and disseminating those conclusions to others. Agreement on accepted methods before a multidisciplinary project starts can help prevent later difficulties.

Recommendation

- Researchers have the primary responsibility for upholding standards of responsible conduct in research. They should employ the expected standards of their fields, observe applicable laws and regulations, be willing to share data with others, and agree on the standards to be observed in multidisciplinary collaborations.

Irresponsible Practices in Research

As explained in the introduction, this guide does not attempt to define research integrity in legal terms. Instead, it treats breaches of research integrity as transgressions of the moral, ethical, or legal boundaries based on the fundamental values underlying research. As noted previously, many national and international bodies have grappled with these issues in recent years, and have generated insights on research integrity, codes of conduct, and lessons for institutions and countries establishing systems for dealing with irresponsible conduct (for example, ESF 2010 and ESF-ALLEA, 2011). Transgressions may be of a lesser or greater extent and thus may require different levels of investigation and penalty. Also, responses to irresponsible actions can differ from place to place and time to time. The individuals and institutions charged with responding to such actions need to take all of these factors into account.

Irresponsible practices in the conduct of research can take many forms. Among the most egregious are those that violate the trust underlying research by introducing fraudulent results into science or scholarship or by stealing ideas. These acts include fabrication, which is "making up results and recording them as if they were real"; falsification, which is "manipulating research processes or changing or omitting data"; and plagiarism, which is "appropriating another person's material (ideas, research results, or words) without giving proper credit" (ESF-ALLEA, 2011).

Fraudulent acts can include what may seem like minor transgressions. For example, researchers might be tempted to use only some of the data generated in an experiment and discard data that do not meet expectations. However, such actions violate researchers' fundamental obligation to produce reliable and objective results. When senior scientists in the past have been suspected of cutting corners or ignoring inconvenient data, they have been judged harshly.

Fraudulent research can be extremely harmful to researchers and to

society. It can result in the production of deficient products, inadequate instruments, or erroneous procedures. Policy or legislation can be based on incorrect findings. The public's trust in science and scholarship can be damaged. The fabrication or falsification of results can end a researcher's career, discredit colleagues, and damage the entire research enterprise.

Plagiarism may seem to be a less severe transgression than fabrication or falsification, and it does not have the effect of introducing fraudulent results into research. However, because it is based on deceiving other researchers, it, too, weakens the foundation of trust on which research is based. Similarly, publishing or duplicating exactly the same material in more than one place—a practice that has become commonly known as self-plagiarism—is dishonest since publishers and readers expect published material to be original, and it squanders the resources available to do research and publish results. Electronic communications have made it both easier to plagiarize material and easier to detect plagiarism, but such means of communication have not changed the expectation that published material is not copied from somewhere else.

The boundary between unacceptable and acceptable behavior is not always clear. For example, a researcher may use methodologically unsound data processing, questionable analytical or statistical techniques, or inadequate control groups. A case study may not be representative of the phenomena it is purported to represent. Economic, ideological, or personal interests may skew the outcomes of research. Plagiarism may range from the wholesale theft of long passages of text to the careless or perhaps inadvertent use of another's ideas. In all of these cases, it may be impossible to determine whether a researcher set out to deceive. Furthermore, researchers are human and can make mistakes. In such cases, these mistakes need to be openly acknowledged so that the scholarly record can be corrected (see Box 3-2).

Standards and expectations can change over time. For example, using significant blocks of text from one's own thesis or dissertation without quotation marks in subsequent journal articles may not have been considered an irresponsible practice in the past in certain fields, whereas today it probably would be. A sense of fairness and proportion should be maintained when using new technologies to evaluate behavior that occurred at a time when different standards prevailed.

Beyond fraudulent acts are a host of actions that may not involve the intent to deceive but nevertheless can damage the integrity of research results. Inadequately managing and storing data, withholding data from colleagues who want to replicate the findings, and not preserving original

BOX 3-2
Neutrinos

In 2011 a group of physics researchers in Italy reported an experimental finding that neutrinos had traveled faster than the speed of light (BBC, 2012). If confirmed, this result would have contradicted more than a century of physics research based on the assumption that nothing exceeds the speed of light, and disproved Einstein's 1905 Special Theory of Relativity.

In making the announcement, the leader of the research group urged caution, stating that the group had tried and failed to find a mistake in the research, and that it was time for the community to examine and try to replicate the work. Still, the announcement was widely publicized. Experiments in 2012 performed by a different group at the same laboratory found that neutrinos travel at the same speed as light.

This story illustrates that honest errors can occur in research, and that these can be corrected through subsequent work. The story also raises the question of when and how research groups and institutions should announce or publicize results that would be considered revolutionary or anomalous.

data for the minimum time period specified by the discipline or required by law all constitute irresponsible practices in research. Bad research procedures include "insufficient care for human subjects, animals or cultural objects; violation of protocols; failure to obtain informed consent; breach of confidentiality;" (ESF-ALLEA, 2011) and lack of care in designing or undertaking experiments.

Finally, some irresponsible actions may not damage the research record but are inappropriate in any workplace. These include intimidating or harassing students or assistants, inadequate mentoring or counseling of students, misrepresentation of credentials, insensitivity to social or cultural norms, prejudice against members of particular groups or gender, misuse of funds, failure to disclose conflicts of interests, and other breaches of general social and moral principles. The same procedures used to respond to irresponsible conduct in research may be enlisted in responding to such actions, but all workplaces should have procedures for dealing with these problems.

Some research organizations and funding agencies draw a sharp distinction between falsification, fabrication, and plagiarism and other irresponsible actions in research (ESF-ALLEA, 2011). They may further specify that falsification, fabrication, or plagiarism need to be committed intentionally, knowingly, or recklessly to fall into the category of research "misconduct" or "fraud." Other institutions define research misconduct more broadly to include such actions as misrepresentation of interests, breach of confidentiality, abuse of research subjects, inappropriate authorship, covering up misconduct, or reprisals against whistle-blowers who report misconduct.

Irresponsible practices other than falsification, fabrication, and plagiarism may not lead to formal allegations of misconduct. However, they can be just as damaging to research, to researchers, and to the relationship between the research community and society. Researchers have a responsibility to themselves, to the research community, and to the public to avoid actions that can be interpreted as irresponsible.

Recommendation

▶ Researchers have an obligation to themselves, their colleagues, and society to avoid both the egregious transgressions of falsification, fabrication, and plagiarism and the other forms of irresponsible conduct that can undermine the research enterprise.

Responding to Irresponsible Research Practices

It can be very difficult to raise concerns about the actions of another researcher, especially when that person is in a position of authority. But researchers cannot uphold the fundamental values of research while ignoring irresponsible research practices.

Many concerns can be addressed by talking with someone else within a research group, perhaps someone who has been designated as a point of contact on research practices. However, people who have concerns about the actions of another researcher need to have more than one way to make those concerns known. Some institutions have independent ombudsmen to whom anyone can refer issues about irresponsible practices. Others have designated agencies, offices, or individuals responsible for hearing allegations and determining the appropriate course of action. Procedures differ among organizations and among countries, but all researchers need someone with whom they can consult if they have witnessed or suspect irresponsible practices.

In addition, experience indicates that a full solution to some problems cannot depend only on research institutions but also requires an independent organization that can handle allegations and remind researchers and institutions of their responsibilities. Researchers need points of contact both within and outside research institutions with whom they can raise concerns and discuss issues. Training of researchers needs to include information about such options.

In responding to reports of irresponsible practices in research, some principles should be universally observed. Whistle-blowers should be protected from unjust reprisals. Those accused of irresponsible practices need to be treated fairly. Due process, proper communication during an investigation, and fair adjudication are essential. Humans are fallible, which means that accusations of research misconduct may be mistaken or malicious. The groups handling such accusations have a heavy responsibility. Freedom of belief, research, and speech must be accorded equally to the accused and the accuser.

Primary responsibility for handling cases of misconduct should be in the hands of the employers of researchers. Each institution should have a standing committee that deals with misconduct, or it should establish an ad hoc committee when serious allegations of misconduct are made. Many institutions, and even entire countries, may try to downplay instances of misconduct to avoid negative publicity. But institutions that deal forthrightly and openly with problems generally fare better than those that try

to cover them up. Overcoming a culture of face saving can make an institution and the entire research enterprise stronger.

The first and most important aspect of attention to misconduct in research is its prevention. The research institutions that employ researchers need to create a culture that values high standards of conduct and minimizes incentives to violate those standards. The leaders of research institutions, laboratory and department heads, research funding agencies, journal editors, and others need to act as role models for the management and governance of research. All researchers and staff need to receive formal and informal training in responsible research practices.

Recommendation

▶ Researchers have a responsibility to maintain high standards of responsible conduct and to take appropriate actions when they witness or suspect irresponsible conduct.

Handling Issues of Responsible Conduct in International Research

International collaborations require particular attention to issues of responsible conduct. Such collaborations typically take place under two different circumstances. An individual researcher or research team might invite a foreign colleague, postdoctoral fellow, or student to participate in the research. In this case, the rules of conduct of the host institute apply to the guest researcher as well. The guest researcher should be thoroughly familiar with these rules and agree to abide by them.

Alternately, two or more researchers or groups of researchers from different countries may decide to work together on a research project. In this case, national codes or procedures may be at variance or even contradict each other. Under these circumstances, the codes and procedures to be followed need to be specified before the start of the collaboration. Potential problems such as dual-use and intellectual property issues should be addressed beforehand (Faden and Karron, 2012). The general order of authorship should be established along with agreements on how to share data, raw or otherwise, to guarantee scientific best practice. Experimental procedures should be adapted to the respective and available infrastructures, and materials produced as part of the collaboration should avoid nonscientific statements and be peer reviewed.

The European Code of Conduct (ESF-ALLEA, 2010) recommends that international collaborations follow the guidance of the Organization for

Economic Cooperation and Development Global Science Forum (OECD, 2007). The forum has produced example text for international agreements that can be embodied in the formal documents for collaborative projects.

Recommendation

- Guidelines for responsible conduct and procedures to address irresponsible research practices need to be established in the initial stages of international collaborations.

Reporting Research Results

Strictly speaking, research results do not enter the realm of science or scholarship until they are made public. Data or research conclusions that remain private may inform the publicly disseminated work of a researcher or research group, but they need to be available to others to become a formal part of the archive of human knowledge.

Publication of research results can take many forms: talks or poster presentations in conferences, journal articles, comments, reports, chapters, books, and so on. All of these types of publications need to observe the essential values of honesty, fairness, and openness. In addition, some types of communications have specific considerations regarding social responsibility, intellectual property, and other issues.

Many kinds of irresponsible and undesirable practices are associated with publication. These include both claiming or granting undeserved authorship and denying deserved authorship, manipulating images so as to provide a deceptive impression of research results, repeating publications, publishing results in "least publishable units" to a degree where the novelty of the publication is questionable to maximize the quantity of publications, insufficient acknowledgment of contributors or sponsors, conflicts of interest or bias in reviewing, and appropriating ideas from papers before publication.

In recent years, irresponsible actions associated with clinical trials of pharmaceutical products have received increased scrutiny (Fairman and Curtiss, 2009). The best-known case might be the withdrawal of the pain reliever Vioxx from the U.S. market in 2004 following disclosures that its maker, Merck, withheld information about the drug's risks. Irresponsible behavior such as selective reporting of results and bias resulting from undisclosed conflicts of interest on the part of investigators are certainly

not limited to for-profit companies. Still, areas of research where the results have significant effect on the health of the public, with clinical trials being a prominent example, deserve particular attention in efforts to ensure research integrity.

Peer Review

In the context of publication, peer review involves the prepublication evaluation by experts of a proposed communication. Peer review seeks to ensure that the communication is relevant, that the evidence supports the conclusions, and that the findings are of value. Peer review can enhance the quality of publications by clarifying explanations, correcting errors, properly allocating credit, and enabling other improvements. Publishing in journals and with publishers known for their high standards of peer review enhances the reputation of authors.

Peer review of proposed publications can take several forms. The most common arrangement is for the reviewer to be anonymous to encourage honest and frank reviews, and most reviewers favor this approach. Another approach is for both the authors and the reviewers to be blinded, although the identities of the authors could possibly be surmised by the reviewers from the subject of the communication and the references cited. A third method is for the entire process to be open, with the reviewers and authors both identified and the comments from both sides made freely available. This practice is most common among journals that provide open access to publications. In a fourth method, either before or after publication all readers and reviewers can access the publication and provide comments, generally in an online forum. Also, many journals have added electronic forums where readers can post comments on a published article. Especially common in the life sciences, this practice has not yet become as formal or institutionalized as to provide a replacement for peer review. At this point, it is not clear what the future balance might be between traditional peer review and alternatives.

Irresponsible practices in peer review can occur when the reviewer is biased for or against the authors or has competing interests. This can result in delays in reviewing or in unwarranted rejection. To minimize such conflicts, some journals allow authors to name persons to whom an article should not be sent for peer review, and editors also can avoid conflicts in their choice of reviewers. If an article is rejected, some editors allow the authors to appeal the decision.

Some authors have complained that a publication has been kept on hold for an unnecessarily long time while a reviewer finishes a competing

publication. Such fears can be especially keen for authors who are at a disadvantage in peer review, including researchers from countries that are not at the center of a research field. Some authors also have complained about racial discrimination in review decisions. Potential reviewers who realize that they have a conflict, a bias, or a lack of needed background knowledge in reviewing a proposed publication have a duty to inform editors so that appropriate actions can be taken.

Peer review sometimes detects fraudulent research, but reviewers generally must trust that the work described was done honestly. Peer review also is not designed primarily to detect other irresponsible practices, such as using public data as if it were the author's own, submitting papers with the same content to different journals, or submitting an article that has already been published in another language without reference to the original.

In some cases, a reviewer may ask for the raw data on which the conclusions of a communication are based. Some journals also require that the raw data be made publicly available as a condition of publication. However, in some research fields, providing raw data is impractical. There may be too much data to communicate easily, the data may be confidential, or intellectual property or national security considerations may restrict the data dissemination. In those fields, other ways need to be found for submitting data to the collective review of peers and making information available to verify and build on results. If material that has not been peer reviewed is used in research, this should be acknowledged so that others may judge the effects of that use on conclusions.

Difficulties can arise in reviewing publications from large collaborative projects involving researchers from different institutions, different countries, or different research disciplines. Reviewers may need to be comparably diverse to judge the multiple aspects of such a publication. Another area of concern has been the communication of dual-use research, such as research results that could contribute to the development of chemical or biological weapons. In such circumstances, reviewers or specially constituted panels may be asked to determine whether the likely benefits of publication outweigh the possible risks.

Recommendation

- Peer reviewers need to assess proposed publications fairly and promptly, with full disclosure of conflicts of interest or bias.

Authorship and Referencing

Researchers in different disciplines and in different countries have varying conventions regarding how authors are listed in research papers. Some of these conventions may vary according to the journal or discipline, or change over time.[6] However, authorship connotes responsibility for the entire contents of that paper unless the paper specifically allocates responsibility among authors. The authors of a discredited paper may claim that they do not have expertise in the part of a paper containing fraudulent or erroneous results, especially in multidisciplinary research. However, if a paper contains fraudulent or erroneous results, all authors will be held accountable for those results. An author without expertise in a particular area may need to ask a trusted colleague to review a paper to have confidence in its accuracy.

Sometimes, the authors of a paper add an author who has not contributed to the paper to increase the prestige of a paper or have the paper published in a prominent journal. Hierarchical pressures in research organizations may lead authors to list laboratory or institute directors who have not contributed. In other cases, a contributor to a paper is not listed. Both "guest authors" and "ghost authors" undermine the standards of research and distort the allocation of credit.

Recommendation

- Researchers should agree in the early stages of a research project as to who will be listed as author in publications emerging from that project and the criteria for determining the order of the authors.

Communicating with Policy Makers and the Public

The public's trust in research depends on the honesty, openness, and objectivity of researchers in communicating the results of research to those outside the research community. This responsibility can take time away from research, but public communication is essential given the pervasive influence of research on the broader society.

Researchers have the same rights as all other people in expressing their opinions and seeking to influence public policy. But researchers must be especially careful to distinguish their roles as specialists and as advocates.

6 For example, Nijman (2012) calls for a clear editorial policy for deceased authors, in order to ensure that deceased collaborators receive appropriate credit.

Researchers who choose to be advocates have a special responsibility to themselves and to the research community to be very open and honest about the support for the statements they make. Researchers should resist speaking or writing with the authority of science or scholarship on complex, unresolved topics outside their areas of expertise. Researchers can risk their credibility by becoming advocates for public policy issues that can be resolved only with inputs from outside the research community.

A particular problem is communicating uncertainties or probabilities clearly and comprehensively. Statistical evidence can be counterintuitive[7] or poorly grounded.[8] Moreover, uncertainty about measured quantities differs from the uncertainties associated with model calculations.[9] A particular need is for cogent theory and explicit methodology in integrating uncertainty estimates across studies inside the same discipline but with different starting points.

At the same time, all researchers have information of value that they can convey to policy makers and the public, and researchers are particularly well suited to act as honest brokers to untangle basic facts from economic, social, and political considerations. Today, new tools of communication such as blogs and videos are providing innovative ways for researchers to engage with the public. New communication tools also are enabling the development of peer communities around issues of regulatory or policy relevance. The widespread dissemination of solid peer-reviewed information benefits both research and the society in which research is embedded.

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7 Suppose that the probability of a woman having breast cancer is 0.8 percent, and that if a woman has breast cancer there is a 90 percent chance that her mammogram will turn up positive. But because mammography is imperfect, there is a 7 percent chance that a mammogram will be positive even when a woman does not have breast cancer. What are the odds that a woman whose mammogram has turned up positive actually has breast cancer? When posed to doctors the answers vary hugely, from 1 percent to 90 percent. The correct answer that the probability that a woman with a positive mammogram has breast cancer in this example is only 9 percent (Zhong, 2011; see also: http://betterexplained.com/articles/an-intuitive-and-short-explanation-of-bayes-theorem/. Accessed 26 July 2012).

8 For example, in balancing between scientific freedom and fears of bioterrorism in the contentious cases of engineered H5N1 influenza virus strains, a difficult quandary was the number of experimental animals (ferrets) used to study the transmission of flu viruses. In a news article in *Science* (Cohen, 2012), one of the authors is quoted as follows: "We have to be really, really careful to interpret our data in ferret transmission in a quantitative way. You cannot say if you got two out of four transmissions that your virus is 50 transmissible." Indeed!

9 For example, Chapter 3 of the report *Climate change assessments: Review of the processes and procedures of the IPCC* (IAC, 2010) describes confusion that arose over policy advice offered in the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC, 2007).

Recommendation

- Researchers need to communicate the policy implications of their results clearly and comprehensively to policy makers and the public—including a clear assessment of the uncertainties associated with their results—while avoiding advocacy based on their authority as researchers.

Policy Advice

Researchers often are called upon to serve as advisers to governments, industry, or nongovernmental organizations. This advice can be extremely influential and must avoid bias or parochialism.

Documents generated by researchers to provide advice differ from research articles, but they, too, are based on evidence and reason. These documents should be peer reviewed to bring the quality control mechanisms of research to bear on public and private advice. If formal peer review is not possible, informal consultations with peers, including those who would be expected to be critical, may be necessary.

Recommendation

- Scientific policy advice to governments, industry, or nongovernmental organizations should undergo peer review and should not be made from an advocacy perspective.

Institutional Responsibilities

Many institutions are involved in the research process, including government funding agencies, private funders, international organizations, government research institutions, universities, journals, publishers, professional societies, and national academies. Each of these institutions has responsibilities in establishing and upholding standards of responsible conduct in research.

Universities and Other Research Institutions

The institutions that employ researchers and provide a setting for their work have a special set of responsibilities. These institutions need clear, well-communicated rules that define irresponsible conduct. They also

need impartial and confidential mechanisms to report and investigate suspected breaches of these rules. Investigations should take place as quickly as possible. The rights of the accused should be protected, and whistle-blowers should be protected from retaliation. The response to findings of irresponsible practices should ensure that the research record is correct, with sanctions serving as a deterrent to others.

Institutions have the responsibility to establish impartial and confidential mechanisms for reporting misconduct. Laboratory and department heads need to be seen as trusted points of contact for discussing concerns. In addition, researchers, research staff, and students need access to independent individuals to whom they can turn. Some countries have had good experiences with independent ombudsmen who can handle issues of irresponsible conduct both on an institutional level and on a national level. Ombudsmen generally do not have the power to initiate investigations, but should be able to require institutional or independent investigations, of suspected irresponsible practices. In other cases, integrity officers at institutions serve as an independent point of contact for concerned researchers.

An additional set of institutional responsibilities relates to the education, training, and mentoring of researchers, research staff, and students. Prevention of irresponsible practices is more important than remedies and punishments and yet is given too little attention in practice. All researchers need opportunities to learn about the values and principles on which good research is based. Responsible conduct should be an element of all courses and research experiences so that it is seen as fundamental to the research enterprise and not as a separate component.

Research institutions also have a responsibility for maintaining an environment that fosters research integrity. The fundamental values of research need to be practiced and emphasized as a matter of routine. Experienced researchers need to convey to students and younger colleagues the standards of research through teaching, through the examples they set, and through mentoring.

Institutions that employ researchers thrive when they emphasize excellence and creativity. In recent years, hiring, promotion, and funding decisions have made increased use of such metrics as the number of citations a publication has received or the "impact factor" of a journal calculated from citation of articles in that journal. However, too much emphasis on such metrics can be misleading and can distort incentive systems in research in harmful ways. Quality cannot always be measured by numbers, since

research consists of many activities other than publishing. Researchers may try to publish as many articles as possible and reduce the quality of their articles as a result. And journals may encourage their authors to cite papers from that journal to improve its ranking (Wilhite and Fong, 2012). While metrics have their uses, explicit policies that limit their effects may be needed to stem abuses.

Recommendation

- Research institutions need to establish clear, well-communicated rules that define irresponsible conduct and ensure that all researchers, research staff, and students are trained in the application of these rules to research. They should establish effective mechanisms for addressing allegations of research misconduct. Research institutions also need to create an environment that fosters research integrity through education, training, and mentoring and by embracing incentives that deter irresponsible actions.

Public and Private Research Funding Agencies

The public and private agencies that support research, including governments, philanthropies, and industry, also have important responsibilities. In many ways, these mirror the responsibilities of the researchers and research institutions that they support.

At a fundamental level, funding agencies should make their best efforts to ensure that they support the best research possible. This means taking care that their funding policies do not promote an environment where researchers face strong incentives to publish as many papers as possible in a short period of time, or face other pressures to lower the quality of research or compromise integrity.

Researchers are responsible for the proper handling of the funds entrusted to them, but funding agencies, whether public or private, have the power to insist on responsible research practices. They therefore have the right to insist upon the application of appropriate and transparent rules of research conduct. Funders have the corresponding duty to provide funding sufficient to ensure that researchers and research institutions can put systems in place that uphold integrity and facilitate high-quality research.

In other respects, the power of funding agencies is more limited. For example, they do not have the right to exert control over research for political reasons. Also, unless a researcher has signed a contract imposing limits on publication, that researcher has the right to publish research results without institutional constraints.

Recommendation

- Public and private funding agencies should avoid policies that might lead to overemphasis of quantity over quality in the reward systems for researchers. They should provide support to researchers and research institutions at a level sufficient to ensure that research can be undertaken properly and responsibly, without compromising quality or integrity. Funding agencies should also support efforts of research institutions to develop education and training programs on responsible research conduct. They should require research institutions to have mechanisms in place to respond to irresponsible practices. When supporting international research collaborations, funding agencies should make sure that rules are clear and understood by all parties to the collaboration in advance.

Journals

As repositories of the research literature, journals have a responsibility to maintain the integrity of research results. This entails establishing not only proper peer-review processes but also proper handling of retractions. When a published paper is shown to be based on fraudulent data, journals have a responsibility to issue a correction or retract the paper. However, many such papers continue to be cited because journals do not provide an obvious way of knowing that a paper has been corrected or retracted. Also, journals are generally reluctant to communicate whether a retraction was the result of an honest error or misconduct, sometimes because national laws prohibit potential libel of authors.

Maintaining the integrity of the research literature requires more than peer review and proper handling of retractions. An increasing number of journals are using software to guard against plagiarism and the inappropriate manipulation of figures. If reviewers raise concerns about errors in a paper, the editors may communicate with the author to determine whether an error was accidental or the result of irresponsible practices, and they may ask the authors for the raw data on which a conclusion is based. If evidence of misconduct surfaces, a journal may inform an

author's institution of the infraction, but this practice is not universal. The Committee on Publication Ethics has established a code of conduct and retraction guidelines and provides advice to editors and publishers on publication ethics (COPE, 2012).

Journals and authors have a responsibility to prevent duplication: the publication of the same work in different journals. There is often value in republishing work in multiple languages, particularly in cases where the original work appears in a less widely spoken language. The circumstances of such republication should be made clear to editors at the time of submission and to readers. Editors should also refrain from encouraging or coercing authors to add citations from the journal in order to boost the journal's impact factor (Wilhite and Fong, 2012).

Journals add value to the publishing process, and they must be economically viable to exist. Yet, to the extent that they are freely and widely available, research results increase in public value. The balance between economic viability and openness is changing as electronic communications continue to supplement and increasingly replace traditional paper publications, but whether and how this tension will be resolved is not yet clear. Many journals (but not yet all) allow a researcher to post a published paper on the World Wide Web. Some funding agencies require that journal articles become publicly available within a specified time after publication. Some journals and publishers provide free and open access to publications and rely on sources of revenue other than subscriptions or access charges.

The role of journals in addressing possible dual-use issues in reported results is somewhat recent. In 2003 the editors of some influential journals agreed to review such articles for biosecurity concerns in addition to the standard peer-review process (Associated Press, 2003).

Recommendation

- Journals should use technological means to protect the integrity of the research literature. They should make retractions visible so that retracted papers are not used or cited. Both authors and journals should take steps to avoid duplicated publications that readers expect to be original and should refrain from citations designed only to boost the journal's impact factor.

The Roles of National Academies and Interacademy Organizations

Academies and interacademy organizations should provide forceful leadership on matters of research conduct. They should help to establish standards for the responsible conduct of research and should play an active role in disseminating those guidelines. This should include communication with younger researchers, perhaps involving academies for young researchers.

Academies that manage research institutes bear the expected responsibility for creating a culture of research integrity and dealing properly with allegations of irresponsible conduct. Other academies have a standing committee on research ethics with an advisory function. Some academies have responsibility for investigating allegations of misconduct among their fellows.

Most academies that do not manage research institutions do not have the capacity to investigate cases of alleged misconduct, reach a verdict, or make recommendations for punishment. Nor do academies have the legal authority to serve as a court of appeal where either the accused or the accuser can lodge an appeal against a decision. However, academies can serve in an advisory role for other organizations in difficult or complicated cases. Academies also can monitor issues involving research conduct and reflect on the basic norms and standards in science and scholarship and on the prevalence, causes, and possible ways of preventing breaches of research integrity. This reflective role can be supported by analyses of the literature, reports of work groups, and conferences.

Academies need to be in constant dialogue with other institutions involved in research. At a regional level, analogous roles can be played by interacademy organizations.

Recommendation

- As the most prestigious national scientific bodies, national academies should provide forceful leadership on issues involving responsible conduct in research, including the establishment and dissemination of standards. They should work within their own scientific communities to ensure that effective mechanisms exist to address allegations of research misconduct. Interacademy organizations can play analogous roles at the regional and global levels.

4. Recommendations for Researchers and Institutions Involved in Research

This final chapter compiles the recommendations that appear earlier in this report, as a brief guide for researchers and for institutions involved in research.

The Research Plan

Researchers have a responsibility to safeguard privileged information and to provide credit when using others' ideas.

Researchers have a responsibility to participate in the review of research proposals and not to abuse the trust on which the review process is based. They should disclose conflicts of interest and treat colleagues fairly in reviewing their ideas. **Research sponsors** should use international reviewers where feasible.

Researchers should bear in mind the possible consequences of their work, including harmful consequences, in planning research projects.

Carrying Out Research

Researchers have the primary responsibility for upholding standards of responsible conduct in research. They should employ the expected standards of their fields, observe applicable laws and regulations, be willing to share data with others, and agree on the standards to be observed in multidisciplinary collaborations.

Researchers have an obligation to themselves, their colleagues, and society to avoid both the egregious transgressions of falsification, fabrication, and plagiarism and the other forms of irresponsible conduct that can undermine the research enterprise.

Researchers have a responsibility to maintain high standards of responsible conduct and to take appropriate actions when they witness or suspect irresponsible conduct.

Guidelines for responsible conduct and procedures to address irresponsible research practices need to be established in the initial stages of international collaborations.

Reporting Research Results

Peer reviewers need to assess proposed publications fairly and promptly, with full disclosure of conflicts of interest or bias.

Researchers should agree in the early stages of a research project as to who will be listed as author in publications emerging from that project and the criteria for determining the order of authors.

Communicating with Policy Makers and the Public

Researchers need to communicate the policy implications of their results clearly and comprehensively to policy makers and the public—including a clear assessment of the uncertainties associated with their results—while avoiding advocacy based on their authority as researchers.

Scientific policy advice to governments, industry, or nongovernmental organizations should undergo peer review and should not be made from an advocacy perspective.

Institutional Responsibilities: Research Institutions, Public and Private Funding Agencies, Journals, and Academies

Research institutions need to establish clear, well-communicated rules that define irresponsible conduct and ensure that all researchers, research staff, and students are trained in the application of these rules to research. They should establish effective mechanisms for addressing allegations of research misconduct. **Research institutions** also need to create an environment that fosters research integrity through education, training, and mentoring and by embracing incentives that deter irresponsible actions.

Public and private funding agencies should avoid policies that might lead to overemphasis of quantity over quality in the reward systems for researchers. They should provide support to researchers and research institutions at a level sufficient to ensure that research can be undertaken properly and responsibly, without compromising quality or integrity. **Funding agencies** should also support efforts of research institutions to develop education and training programs on responsible research conduct.

They should require research institutions to have mechanisms in place to respond to irresponsible practices. When supporting international research collaborations, **funding agencies** should make sure that rules are clear and understood by all parties to the collaboration in advance.

Journals should use technological means to protect the integrity of the research literature. They should make retractions visible so that retracted papers are not used or cited. **Both authors and journals** should take steps to avoid duplicated publications that readers expect to be original and should refrain from citations designed only to boost the journal's impact factor.

As the most prestigious national scientific bodies, **national academies** should provide forceful leadership on issues involving responsible conduct in research, including the establishment and dissemination of standards. They should work within their own scientific communities to ensure that effective mechanisms exist to address allegations of research misconduct. **Interacademy organizations** can play analogous roles at the regional and global levels.

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Biographical Sketches of Committee Members

Indira NATH (Co-Chair) is Raja Ramanna Fellow and Emeritus Professor, National Institute of Pathology (ICMR), Safdarjung Hospital Campus, New Delhi, India. She received an MBBS from the All India Institute of Medical Sciences (AIIMS), New Delhi, and later served on the Faculty of AIIMS, making pioneering contributions to immunology research by her seminal work on cellular immune responses in human leprosy and a search for markers for viability of the leprosy bacillus which is not cultivable. She has also mentored many MBiotech, MD, and PhD students and made contributions to education, medical and science policies, and women scientists' issues. She was a member of the Scientific Advisory Committee to Cabinet, Foreign Secretary INSA (1995–1997), council member (1992–1994 and 1998–2006) and vice president (2001–2003) of the Indian Academy of Sciences, Bangalore, and chairperson, Women Scientists Programme, DST (2003). She was conferred numerous awards, notably: Padmashri (1999), Chevalier Ordre National du Merite, France (2003), Silver Banner, Tuscany, Italy (2003), L'Oreal UNESCO Award for Women in Science (Asia Pacific) (2002), SS Bhatnagar Award (1983), and the Basanti Devi Amir Chand Award by ICMR (1994). She was elected fellow of the Indian National Science Academy, Delhi; National Academy of Sciences (India), Allahabad (1988); Indian Academy of Sciences, Bangalore (1990); National Academy of Medical Sciences (India) (1992); Royal College of Pathology (1992); and the Academy of Sciences for the Developing World (TWAS) (1995). She was conferred a DSc (hc) 2002, by Pierre and Marie Curie University, Paris, France.

Professor Ernst-Ludwig WINNACKER (Co-Chair) is secretary general of the Human Frontier Science Program Organization (HFSPO). He studied chemistry at the Swiss Federal Institute of Technology (ETH Zurich) where he obtained his PhD in 1968. After postdoctoral work at the University of California in Berkeley and the Karolinska Institute in Stockholm from 1968 to 1972, he became assistant and then DFG Visiting Professor at the Institute for Genetics, University of Cologne. In 1977 he was appointed associate professor at the Institute of Biochemistry at the Ludwig Maximilians University of Munich, where he was made full professor in 1980. From 1984 to 1997, he was director of the Laboratory of Molecular Biology at the University of Munich Gene Center. He served as president of the German Research Foundation (DFG) from 1998 to 2006. From 2003 to 2004 he also chaired the European Heads of Research Councils (EUROHORCs). He served as secretary general of the European Research Council (ERC) from 2007 to 2009. Professor Winnacker is a member of the U.S. National Academy of Sciences, Institute of Medicine, and of the German Academy of Sciences Leopoldina. His main fields of research are virus-cell interaction, the mechanisms of gene expression in higher cells, and prion diseases.

Professor Renfrew CHRISTIE has been dean of research at the University of the Western Cape, South Africa, for 22 years. A specialist in the politics and economics of energy, and in the history of science and technology, his Oxford doctorate treated the electrification of South Africa over 70 years. A whistle-blower for

the African National Congress, on the apartheid nuclear weapons program, he was imprisoned for terrorism for seven and a half years in Pretoria. He cofounded the Macro Economic Research Group and the National Institute for Economic policy, which helped set South Africa's economy right after apartheid. He holds the Certificate of Commendation of the Chief of the South African Navy, for contributions to the democratic transformation of the South African Navy after apartheid. For 22 years he has been a member of the Board of Trustees of South Africa's premier human rights law unit, the UWC Community Law Centre, and has chaired the board for 15 years. His handwriting was on the second draft of the South African Bill of Rights. He is a defence force service commissioner, whose task is to advise the minister on the conditions of service of South Africa's troops. He has chaired the South African Commonwealth Scholarships Selection Committee for 15 years. He has held visiting fellowships in the Woodrow Wilson International Center for Scholars, Washington D.C.; the Stiftung fur Wissenschaft und Politik, then in Ebenhausen; and the Indian Ocean Peace Centre, in Perth, Western Australia. He has had the privilege of addressing the Groupe Crises of the Institut de France on the Quai de Conti, Paris. He attended both the Lisbon and Singapore World Conferences on Research Integrity. He is a signatory on the Singapore Statement on Research Integrity. He is a member of the Academy of Science of South Africa and a fellow of the Royal Society of South Africa.

Pieter J. D. DRENTH studied psychology from 1952 to 1958, and received his PhD in 1960 at the VU University Amsterdam. With a Fulbright scholarship, he studied and worked in the United States (New York University and Standard Oil Co. of New Jersey) from 1960 to 1961. From 1962 to 1967 he was lecturer in test theory and statistics, and from 1967 to 2006 he was professor in test and scale theory and work and organisational psychology at the VU University Amsterdam. He was visiting professor at Washington University in St. Louis, (1966) and the University of Washington, Seattle (1977). From 1982 to 1987 he was Rector Magnificus at the VU University Amsterdam, and from 1990 to 1996 he was president of the Royal Netherlands Academy of Arts and Sciences. From 2000 to 2006 he was president, and since 2006 has been honorary president, of ALL European Academies (ALLEA, the European federation of national academies of sciences and humanities). For his scientific work he received two honorary doctorates (Gent, 1981, and Paris Sorbonne, 1996). Her Majesty the Queen of the Netherlands conferred on him the knighthood in the order of the Netherlands' Lion (1990) and the commandership in the order of Oranje Nassau (1996).

Paula KIVIMAA received her PhD in organizations and management and is a senior researcher at the Finnish Environment Institute, a government research organization in Finland. Since 2003 she has carried out research on the emergence of eco-innovations in energy and forest sectors and on policy evaluation related to climate, energy, and innovation policies. Her current research focuses on innovations in energy and transport systems and on climate policy integration. Dr. Kivimaa obtained her PhD from Helsinki School of Economics in 2008. In 2009 she was an IAP-selected Young Scientist in the World Economic Forum Annual Meeting of the New Champions. In 2010 she was among the Young Scientists who established a global organization of early-career scientists, Global Young Academy, and acted as an executive committee member during the first year of operation.

Professor LI Zhenzhen works as a research fellow in the Institute of Policy and Management, Chinese Academy of Sciences (IPM-CAS), where she serves as the director of the Research Department of Policy for

Science and Technology Development and the Research Section of Science, Technology and Society. In addition, she is the director of the Research Center for Ethics of Science and Technology, Chinese Academy of Sciences (RCEST-CAS) and Research Center for Academic Morality and Scientific Ethics, Academic Divisions of the Chinese Academy of Sciences (RCAMSE-CASAD), and the executive deputy editor in chief for the academic journal *Science and Society*. Her research interests mainly lie in the field of social studies of science, ethics of science and technology, as well as science and technology policy. In recent years, she has taken charge of major research projects funded by the National Natural Science Foundation of China, Ministry of Science and Technology of China, China Association for Science and Technology, and Chinese Academy of Sciences. In addition, she has been involved in several consultation projects associated with scientific affairs for government departments and civil society, and has participated in drafting policy papers and reviewing law texts.

José A. LOZANO received his PhD in geology from Columbia University in 1974. He is a retired professor of the National University of Colombia (1963–1991), where he occupied several academic administrative positions and was a member of varied administrative academic committees. Professor Lozano is presently general secretary (elected) and executive secretary (appointed) of the Colombian Academy of Exact, Physical and Natural Sciences. He is a correspondent member of the Spanish Academy of Sciences, the focal point for Colombia of the Interamerican Network of Academies of Sciences (IANAS) Science Education Program, president of the Colombian Formation Environmental Net (Red Colombiana de Formación Ambiental), and secretary of the Professional Colombian Council of Geology. His interests encompass science education, capacity building, earth system science with emphasis in marine geology, and environmental sciences and policies. His previous positions include director of the Marine Research Institute, José Benito Vives de Andréis Marine and Coastal Research Institute (INVEMAR), Punta de Betín, Santa Marta (1979–1981); adjunct professor, Earth Sciences and Resources Institute, University of South Carolina (1987–1990); national correspondent of the IUGS Commission for Marine Geology (1982–1990); chairman of the National Committee International Geosphere, Biosphere Programme (IGBP) (1993–2004); secretary of the Caribbean Scientific Union (CCC) (2005–2007); and coordinator of the IANAS Science Education Program (2006–2010).

Barbara SCHAAL is the Mary Dell Chilton Distinguished Professor in Arts and Sciences, Washington University in St. Louis. She currently serves as vice president of the U.S. National Academy of Sciences, chair of the Division on Earth and Life Studies at the National Research Council, and is a member of President Obama's Council of Advisors for Science and Technology. She is a plant evolutionary biologist who uses DNA sequences to understand evolutionary processes such as gene flow, geographical differentiation, and the domestication of crop species. Her current research focuses on the evolutionary genomics of rice. Professor Schaal was born in Berlin, Germany, and grew up in Chicago, Illinois. She graduated from the University of Illinois at Chicago with a degree in biology and received a PhD from Yale University. She has been president of the Botanical Society of America and the Society for the Study of Evolution and is an elected member of the U.S. National Academy of Sciences and the American Academy of Arts and Sciences.

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