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Among the very basic principles that guide scientists, as well as many other scholars, are those expressed as respect for the integrity of knowledge, collegiality, honesty, objectivity, and openness. These principles are at work in the fundamental elements of the scientific method, such as formulating a hypothesis, designing an experiment to test the hypothesis, and collecting and interpreting data. In addition, more particular principles characteristic of specific scientific disciplines influence the methods of observation; the acquisition, storage, management, and sharing of data; the communication of scientific knowledge and information; and the training of younger scientists. The basic and particular principles that guide scientific research practices exist primarily in an unwritten code of ethics. Although some have proposed that these principles should be written down and formalized, 2 the principles and traditions of science are, for the most part, conveyed to successive generations of scientists through example, discussion, and informal education. As was pointed out in an early Academy report on responsible conduct of research in the Page 37 Share Cite Suggested Citation: Responsible Science, Volume I: Ensuring the Integrity of the Research Process. The National Academies Press. Physicist Richard Feynman invoked the informal approach to communicating the basic principles of science in his commencement address at the California Institute of Technology Feynman, Details that could throw doubt on your interpretation must be given, if you know them. You must do the best you canâ€"if you know anything at all wrong, or possibly wrongâ€"to explain it. If you make a theory, for example, and advertise it, or put it out, then you must also put down all the facts that disagree with it, as well as those that agree with it. In summary, the idea is to try to give all the information to help others to judge the value of your contribution, not just the information that leads to judgment in one particular direction or another. Even in a revolutionary scientific field like molecular biology, students and trainees have learned the basic principles governing judgments made in such standardized procedures as cloning a new gene and determining its sequence. In evaluating practices that guide research endeavors, it is important to consider the individual character of scientific fields. Research fields that yield highly replicable results, such as ordinary organic chemical structures, are quite different from fields such as cellular immunology, which are in a much earlier stage of development and accumulate much erroneous or uninterpretable material before the pieces fit together coherently. When a research field is too new or too fragmented to support consensual paradigms or established methods, different scientific practices can emerge. Page 38 Share Cite Suggested Citation: This knowledge is based on explanatory principles whose verifiable consequences can be tested by independent observers. Science encompasses a large body of evidence collected by repeated observations and experiments. Although its goal is to approach true explanations as closely as possible, its investigators claim no final or permanent explanatory truths. Verifiable facts always take precedence. Scientists operate within a system designed for continuous testing, where corrections and new findings are announced in refereed scientific publications. The task of systematizing and extending the understanding of the universe is advanced by eliminating disproved ideas and by formulating new tests of others until one emerges as the most probable explanation for any given observed phenomenon. This is called the scientific method. An idea that has not yet been sufficiently tested is called a hypothesis. Different hypotheses are sometimes advanced to explain the same factual evidence. Rigor in the testing of hypotheses is the heart of science, if no verifiable tests can be formulated, the idea is called an ad hoc hypothesisâ€"one that is not fruitful; such hypotheses fail to stimulate research and are unlikely to advance scientific knowledge. A fruitful hypothesis may develop into a theory after substantial observational or experimental support has accumulated. When a hypothesis has survived repeated opportunities for disproof and when competing hypotheses have been eliminated as a result of failure to produce the predicted consequences, that hypothesis may become the accepted theory explaining the original facts. Scientific theories are also predictive. They allow us to anticipate yet unknown phenomena and thus to focus research on more narrowly defined areas. If the results of testing agree with predictions from a theory, the theory is provisionally corroborated. If not, it is proved false and must be either abandoned or modified to account for the inconsistency. Scientific theories, therefore, are accepted only provisionally. It is always possible that a theory that has withstood previous testing may eventually be disproved. But as theories survive more tests, they are regarded with higher levels of confidence. In science, then, facts are determined by observation or measurement of natural or experimental phenomena. A hypothesis is a proposed explanation of those facts. A theory is a hypothesis that has gained wide acceptance because it has survived rigorous investigation of its predictions. Page 39 Share Cite Suggested Citation: Examples of events changing scientific thought are legion. Truly scientific understanding cannot be attained or even pursued effectively when explanations not derived from or tested by the scientific method are accepted. A well-established discipline can also experience profound changes during periods of new conceptual insights. In these moments, when scientists must cope with shifting concepts, the matter of what counts as scientific evidence can be subject to dispute. Historian Jan Sapp has described the complex interplay between theory and observation that characterizes the operation of scientific judgment in the selection of research data during revolutionary periods of paradigmatic shift Sapp, , p. It is a matter of negotiation. It is learned, acquired socially; scientists make judgments about what fellow scientists might expect in order to be convincing. What counts as good evidence may be more or less well-defined after a new discipline or specialty is formed; however, at revolutionary stages in science, when new theories and techniques are being put forward, when standards have yet to be negotiated, scientists are less certain as to what others may require of them to be deemed competent and convincing. Explicit statements of the values and traditions that guide research practice have evolved through the disciplines and have been given in textbooks on scientific methodologies. But the responsibilities of the research community and research institutions in assuring individual compliance with scientific principles, traditions, and codes of ethics are not well defined. Research practices are influenced by a variety of factors, including: The general norms of science; The nature of particular scientific disciplines and the traditions of organizing a specific body of scientific knowledge; The example of individual scientists, particularly those who hold positions of authority or respect based on scientific achievements; The policies and procedures of research institutions and funding agencies; and Socially determined expectations. The first three factors have been important in the evolution of modern science. The latter two have acquired more importance in recent times. Norms of Science As members of a professional group, scientists share a set of common values, aspirations, training, and work experiences. A set of general norms are imbedded in the methods and the disciplines of science that guide individual, scientists in the organization and performance of their research efforts and that also provide a basis for nonscientists to understand and evaluate the performance of scientists. But there is uncertainty about the extent to which individual scientists adhere to such norms. Most social scientists conclude that all behavior is influenced to some degree by norms that reflect socially or morally supported patterns of preference when alternative courses of action are possible. The strength of these influences, and the circumstances that may affect them, are not well understood. In a classic statement of the importance of scientific norms, Robert Merton specified four norms as essential for the effective functioning of science: Neither Merton nor other sociologists of science have provided solid empirical evidence for the degree of influence of these norms in a representative sample of scientists. It is clear that the specific influence of norms on the development of scientific research practices is simply not known and that further study of key determinants is required, both theoretically and empirically. Commonsense views, ideologies, and anecdotes will not support a conclusive appraisal. Individual Scientific Disciplines Science comprises individual disciplines that reflect historical developments and the organization of natural and social phenomena for study. Social scientists may have methods for recording research data that differ from the methods of biologists, and scientists who depend on complex instrumentation may have authorship practices different from those of scientists who work in small groups or carry out field studies. Even within a discipline, experimentalists engage in research practices that differ from the procedures followed by theorists. The disciplines have traditionally provided the vital connections between scientific knowledge and its social organization. Scientific societies and scientific journals, some of which have tens of thousands of members and readers, and the peer review processes used by journals and research sponsors are visible forms of the social organization of the disciplines. The power of the disciplines to shape research practices and standards is derived from their ability to provide a common frame of reference in evaluating the significance of new discoveries and theories in science. Disciplinary departments rely primarily on informal social and professional controls to promote responsible behavior and to penalize deviant behavior. These controls, such as social ostracism, the denial of letters of support for future employment, and the withholding of research resources, can deter and penalize unprofessional behavior within research institutions. The Role of Individual Scientists and Research Teams The methods by which individual scientists and students are socialized in the principles and traditions of science are poorly understood. The principles of science and the practices of the disciplines are transmitted by scientists in classroom settings and, perhaps more importantly, in research groups and teams. The social setting of the research group is a strong and valuable characteristic of American science and education. The dynamics of research groups can foster â€"or inhibitâ€"innovation, creativity, education, and collaboration. Page 43 Share Cite Suggested Citation: Individuals in positions of authority are visible and are also influential in determining funding and other support for the career paths of their associates and students. Research directors and department chairs, by virtue of personal example, thus can reinforce, or weaken, the power of disciplinary standards and scientific norms to affect research practices. To the extent that the behavior of senior scientists conforms with general expectations for appropriate scientific and disciplinary practice, the research system is coherent and mutually reinforcing. When the behavior of research directors or department chairs diverges from expectations for good practice, however, the expected norms of science become ambiguous, and their effects are thus weakened. Thus personal example and the perceived behavior of role models and leaders in the research community can be powerful stimuli in shaping the research practices of colleagues, associates, and students. The role of individuals in influencing research practices can vary by research field, institution, or time. The standards and expectations for behavior exemplified by scientists who are highly regarded for their technical competence or creative insight may have greater influence than the standards of others. Individual and group behaviors may also be more influential in times of uncertainty and change in science, especially when new scientific theories, paradigms, or institutional relationships are being established. Institutional Policies Universities, independent institutes, and government and industrial research organizations create the environment in which research is done. As the recipients of federal funds and the institutional sponsors of research activities, administrative officers must comply with regulatory and legal requirements that accompany public support. Academic institutions traditionally have relied on their faculty to ensure that appropriate scientific and disciplinary standards are maintained. A few universities and other research institutions have also adopted policies or guidelines to clarify the principles that their members are expected to observe in the conduct of scientific research. Institutional policies governing research practices can have a powerful effect on research practices if they are commensurate with the norms that apply to a wide spectrum of research investigators. In particular, the process of adopting and implementing strong institutional policies can sensitize the members of those institutions to the potential for ethical problems in their work. Institutional policies can establish explicit standards that institutional officers then have the power to enforce with sanctions and penalties. Institutional policies are limited, however, in their ability to specify the details of every problematic situation, and they can weaken or displace individual professional judgment in such situations. Currently, academic institutions have very few formal policies and programs in specific areas such as authorship, communication and publication, and training and supervision. Government Regulations and Policies Government agencies have developed specific rules and procedures that directly affect research practices in areas such as laboratory safety, the treatment of human and animal research subjects, and the use of toxic or potentially hazardous substances in research. But policies and procedures adopted by some government research agencies to address misconduct in science see Chapter 5 represent a significant new regulatory development in the relationships between research institutions and government sponsors. The standards and criteria used to monitor institutional compliance with an increasing number of government regulations and policies affecting research practices have been a source of significant disagreement and tension within the research community. In recent years, some government research agencies have also adopted policies and procedures for the treatment of research data and materials in their extramural research programs.

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