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A code of ethics for the life sciences

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Abstract The activities of the life sciences are essential to provide solutions for the future, for both individuals and society. Society has demanded growing accountability from the scientific community as implications of life science research rise in influence and there are concerns about the credibility, integrity and motives of science. While the scientific community has responded to concerns about its integrity in part by initiating training in research integrity and the responsible conduct of research, this approach is minimal. The scientific community justifies itself by appealing to the ethos of science, claiming academic freedom, self-direction, and self-regulation, but no comprehensive codification of this foundational ethos has been forthcoming. A review of the professional norms of science and a prototype code of ethics for the life sciences provide a framework to spur discussions within the scientific community to define scientific professionalism. A formalization of implicit principles can provide guidance for recognizing divergence from the norms, place these norms within a context that would enhance education of trainees, and provide a framework for discussing externally and internally applied pressures that are influencing the practice of science. The prototype code articulates the goal for life sciences research and the responsibilities associated with the freedom of exploration, the principles for the practice of science, and the virtues of the scientists themselves. The time is ripe for scientific communities

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to reinvigorate professionalism and define the basis of their social contract. Codifying the basis of the social contract between science and society will sustain public trust in the scientific enterprise.

Keywords Professionalism · Ethics · Code · Research integrity · Life sciences · Norms · Social contract

Introduction

This last decade, society has been startled by many scientific and biotechnological ''breakthroughs''. ''Dolly the sheep'', the human genome project, human embryonic stem cells, gene transfer, transgenic animals, the chimera hu-mouse and the fraud surrounding human ''cloning''. The public response has often been split between wonder and awe versus fear and anger. Society questions, ''Where is science taking us?'' and ''Who is in control?'' The stakes are higher than ever before in human history. Enhanced concerns over bioterrorism have focused attention on the ''dual use'' of knowledge derived from biological research which can be used as easily for malicious purposes such as acts of terrorism as for beneficent purposes like treating infectious diseases [22]. Other concerns surround the power of biology, life sciences, and biomedical techniques; power like the ability to change the genetic makeup of organisms and humans, probe the complexities of the neural system, or intertwine biology with machines. Scientific prowess claims to not only predict our future, cure, or destroy people, and control evolution, but more portentously reframe what it means to be human. While society's first concerns about research have focused on how science will respond to research misconduct by ensuring that data is credible and objective, newer concerns surround science's motivation: for example, how areas are chosen for research, who decides the distribution of scarce research resources, the motives behind scientific inquires and whether it is a conflict of interest for science to police itself. Society is beginning to suspect that science is lobbying for its own benefit and survival rather than acting on behalf of society's best interests.

Most importantly, because science is supported with public funds and conducted in the name of society, there is a tacit social contract that guarantees science will act in the interests of society and accept responsibility for its exploration equal to its demands for resources and professional autonomy. Further the public expects that the scientific enterprise will conduct itself according to high ethical standards. ''...those who exert this power [exert creative energy on nature to uncover its secrets] should subscribe to a set of ethical yardsticks or codes, which help them to identify possible baneful social consequences that either their research methods or the discoveries they disclose create'' [20] (pp. 139–140). ''Maintaining public confidence in the integrity of what we do requires more than assuring ourselves that external financial interests have not tainted our scientific and ethical standards.

We must also reassure the public that we have done everything in our power to ensure that their interests are not sub-ordinate to ours'' [6] (p. 214). Scientific inquiry depends on the scientific community cultivating and maintaining pubic trust.

Research integrity questioned

During the last half of the past century the scientific community's reputation enjoyed the afterglow of scientific positivism: science and technology were believed to not only be able to deliver solutions for what ailed mankind, but positivism espouses that science could ultimately craft utopia. Then high profile misconduct cases of the 80's and 90's threatened the very fabric of scientific inquiry–scientific integrity. Once the credibility of either the data or the scientists was lost; the whole scientific enterprise was jeopardized.

In response to public allegations of scientific misconduct, The Office of Scientific Integrity (OSI) was created in 1989. A primary focus of this office was to investigate research misconduct. Research misconduct was defined as fabrication, falsification, and plagiarism (FFP). Earlier proposals included practices that seriously deviate from those that are commonly accepted within the scientific community for proposing, conducting or reporting research. But identifying practices that represent deviations from commonly accepted practices eluded sufficient definition. Just defining and recognizing misconduct itself is extremely difficult without considering the greater obstacles of prosecuting research misconduct. Complicating this was the strong resistance of the scientific community to externally applied regulations and prosecution as a means to ensure scientific integrity. Rather scientists espoused academic freedom, self-direction and self-regulation. ''Scientists...prefer social constraints and peer pressure to handle misbehavior, including communication with investigators and colleagues and mandated exposure of incorrect results. For scientists, integrity of the scientific community is essential, and that requires communication and trust'' [14] (p. 47).

This resistance eventually led to the creation of the Office of Research Integrity (ORI) which emphasized bolstering scientific integrity through education on research integrity and responsible conduct of research (RCR). ORI has identified nine core areas in which to develop the standards of RCR: (1) data acquisition, management, sharing and ownership; (2) mentor–trainee relationships; (3) publication practices and responsible authorship; (4) peer review; (5) collaborative science; (6) human subjects; (7) research involving animals; (8) research misconduct; and (9) conflict of interest and commitment. While RCR training has become standard practice for research training, there is still a lively debate within the scientific community as to whether the nine core areas identified by ORI are reasonable and/or sufficient.

It is important to note that an appeal to professional autonomy and self-regulation is built on the assumption that professional organizations not only hold a collective norm but effectively enforce it [3]. When queried on how best to preserve scientific integrity, scientists and institutional officials favor transmitting the ethical principles of science from one generation to the next [26]. But this is hindered by a ''*dearth of clear ethical statements*'' [26] (p. 377).

Shift focus to scientific professionalism

The rationale for presenting a prototype code of ethics for the life sciences is to encourage the conversation within the scientific community to define scientific norms and professionalism. Defining scientific professionalism is essential for several reasons. First, scientists have been resistant to the negative connotations associated with research misconduct and what is ''wrong'' with their practices. Scientists have consistently appealed to implicit professional standards and self-regulation. However, an explicit definition of scientific norms and professionalism is necessary to ensure high standards, to judge divergent conduct, and, most importantly, to define the basis for science's social contract with society.

Codifying the standards of practice and the virtues of scientists can provide a framework for scientific professionalism. The responsibility for research integrity is intertwined with both the individual scientist's values and moral commitments, and the whole profession [11]. While ''many academic researchers fear that significant government intervention would jeopardize intellectual freedom and stifle scientific creativity'' [13] (p. S43), they have not been forthcoming in developing an internal professional standard. Inattention creates an ''ethical vacuum'' which by default will result in society resorting to regulation. Codifying a professional standard is the first step in assuring society that the scientific community is committed to the ethos underlying the right to self-regulation. This may defuse the demand for externally proscribed regulation, but whether or not it thwarts the demand for external policies and regulations, articulating principles of scientific professionalism should help make any forthcoming restraints more reasonable for the practice of science.

Cultural influence on science

This emphasis on scientific professionalism and codifying the high standards of science can have an added benefit of providing a framework from which to respond to cultural pressures. Much attention has been focused on the medical profession's transformation due to business pressures. The centerpiece of the medical profession, the physician–patient relationship has been forced into a hybrid business provider–client relationship. Less attention has focused on how these same consumerism pressures are challenging traditional scientific practice. For example, science has increasingly linked justification for research with specific delivery of outcomes. When products have been alluded to or promised, society demands ''translation'' of research knowledge and ''products''. Conflicts of interest and direct links to commercial ties have begun to be addressed, but the impact of consumerism and commercialization on institutional climate itself has not been discussed as forthrightly. Scientists are encountering increasing pressure to deliver funding and/or outcomes such as high profile papers and patents from their efforts. Another trend has been that more research is funded outside of peer review and tied to commercialization of the intellectual activity. This can divorce scientific activity from oversight historically afforded by peer review. An emphasis on public relations and "promoting" research often increases exposure of scientific data at earlier stages of analysis, which inherently inflates individualistic scientific opinion and minimizes the normalization and contextualization of knowledge provided through the scientific community.

Most importantly, science is a universal language where diverse cultures come together in the laboratory. Some argue that ethics is something that should have been learned during childhood and therefore cannot be taught. This argument fails first because scientists come from diverse backgrounds so they do not appeal to the same underlying cultural norms. More to the point, this argument fails because the correct conduct of science cannot have been learned in childhood since many scientific practices (e.g., authorship practices, the confidentiality of peer review) are not elements of childhood. Rather science has an obligation to delineate and transmit its cultural norms to its members.

Prescriptive demands

Another trend in Western culture has been diminishing reliance on theology and philosophy to answer society's questions regarding the meaning of life and the unknown. American pluralistic society now favors secular rationalism for moral justification. Secular rationalism relies heavily on the use of facts to craft arguments. What better source of facts than "scientific" knowledge? This raises the status of science. The public increasingly relies on science and technology to provide information about how people should act. When information is proceeded by the phrases, "a study has proven" or "research has shown", people often change their behavior, especially if they agree with the outcome. Although society may ask science to prescribe action, science must resist accepting this unrealistic adoration of its abilities. While the scientific method is designed to test the natural world, many studies influence metaphysical reflection that deals with the essence of existence and the meaning behind existence. Materialistic experimental methods are inherently unable to address the deeper meaning of the universe and other metaphysical questions.

Science has been popularized, albeit inaccurately, as a morally neutral acquisition of knowledge and science in general as well as individual scientists have been identified as those who "hold the truth". Science as a human and social endeavor is intractably linked to value judgments. Research results are directly influenced by what, why, and how the scientific question was asked. The longed for neutral or distanced observer is unobtainable. The public needs a more realistic appraisal of the capabilities of science. They should be fully aware that the activity of science is full of subjective elements, limitations of knowledge and uncertainties within scientific "findings" and "conclusions". This should not diminish the investment in scientific activity; rather it demands an accurate portrayal of the capabilities of science.

Science must also resist an idealistic portrayal of new discoveries that only depicts the wonder and promise of research ignoring possibilities of failure, possible misuses, or consequences for misuse of new information. As knowledge reaches the public in earlier, less refined forms; the scientific community must reclaim its pivotal role to provide conventional wisdom and contextualization of science. Often the scientific community has blamed the media's and public's appetite for sensational news for the inaccuracies and exaggerations of science. This ignores the reliance of the scientific enterprise itself increasingly using "public relations" to boost an institution's reputation and lobby for greater scientific resources. Furthermore, the public generally lacks the ability to discriminate good research, from preliminary research, or downright fraud. Because the public is often naïve in distinguishing between scientific fact and "opinion", scientists must be aware of the potency of their scientific "opinions" [9]. As scientists and scientific societies increase their advocacy for the science policy agenda, they must recognize these activities are counter-intuitive to both the public perception of the ideology of science [10] and science's social contract. The motivation for scientists is assumed to be altruistic and for the sake of truth itself and not to "*secure personal gain or to promote the supremacy of a particular philosophy or ideology*" [8] (p. 700). New ethical standards for interfacing with the public must be established to meet this trend of public access at all stages of scientific activity.

Need for a code

According to "The Role and Activities of Scientific Societies in Promoting Research Integrity", the report of a conference held in 2000 and jointly sponsored by the AAAS and the US Office of Research Integrity [25] "*codes of ethics should be developed by all scientific disciplines*" [12]. This document consolidated several previous reports and surveys which all identified a need for formalization of the guiding principles for scientific societies. To date, not all professional societies in the life sciences have codified their ethical principles. In the face of "dual use" of scientific information, a scientific code of ethics has been promoted as a weapon to counter bioterrorism [22]. Also the National Advisory Science Board for Biosecurity has developed draft guidance for considerations of a code of conduct for dual use research in life sciences [18]. These particular approaches focus on microbiology and the knowledge generated in that field that could be used to facilitate bioterrorism or biological warfare. However, the implication for the life sciences is greater than misuse for bioterrorism. A broader code is needed to cover universal ethical standards for life science research.

What are professional norms?

Norms are defined as ''a complex set of role characteristics involving specialized knowledge and training, dedication to public service, and autonomous, decision-making authority in matters of importance to society'' [26] (p. 378). Professionalism appeals to standards and mores that are generally subscribed to by the members of the group. Group members then transmit these norms through socialization. Norms are not necessarily codified regulations; instead, they describe fundamental principles for appropriate behavior and relationships within a group, divergence from which is considered a serious offense. Sanctions for these offenses, however, can either be formal or informal [26]. Whether a code can be expected to impact behavior is a matter of debate; however, organizations with a strongly implemented and embedded ethical code of conduct are associated with ethical behavior in the workplace [15].

What are norms for life scientists?

Not all life science societies have published codes of ethics or norms. Nevertheless, within the community of science there are generally agreed upon norms. An often-quoted source for defining the normative structure of science is the work of Robert Merton, which identified four imperatives: universalism, communism, disinterestedness and organized skepticism [16]. Counter norms or alternative norms—particularism, individualism, self-interestedness, and organized dogmatism—were posited to these four norms by Ian Mitroff [17]. ''Universalism'' is the assessment of academic work and individuals' qualifications of appointment, independent of personal characteristics or other irrelevant factors. The counternorm ''particularism'', states that scientists assess new knowledge, and its applications based on reputation and past productivity of the individual or research group. ''Communism'' is the shared ownership of all scientific knowledge, and the full and open communication of all findings as opposed to ''individualism'' (aka solitariness), where scientists protect their newest findings to ensure priority in publishing, patenting, or applications. The third norm ''disinterestedness'' is the separation of research from personal motives and incentives, financial or otherwise, for the sake of the truth and the advancement of knowledge. The counternorm ''self-interestedness'', holds that scientists compete with others in the same field for funding and recognition of their achievements. The fourth norm, ''organized skepticism'' is the reliance on critical review and continually reexamining dogma to further knowledge. The counternorm is ''organized dogmatism'', which holds that scientists invest their careers in promoting their own most important findings, theories, or innovations.

Andre' Cournand [6] and Elizabeth Heitman [13] agreed with and restated the Mertonian norms as honesty, objectivity, tolerance, doubt of certitude and unselfish engagement. Most discussions on the ethics of science would concur with a commitment to intellectual integrity and objectivity as the primary obligations of scientists. Doubt of certitude, similar to organized skepticism, is the readiness to question authorities to advance new knowledge. This principle asserts that no theory or fact is sacred, rather conclusions are always open to further revelation and reinterpretation. Tolerance is the norm based on respect for other's ideas within the scientific community.

Kristin Shrader-Frechette described two prima facie principles for scientific research: ''always report research results with as much objectivity as possible and with no deliberate bias or interpretation'' and ''always present research results in such a way as to avoid their possible misuse and misapplication'' [21] (p. 47). She expanded the concept of objectivity by demanding objectivity on two levels, epistemic (beliefs implicit in the hypotheses and methodologies) and ethical (the researcher's actions). Alongside these norms is the recognition of the inherent level of error in the observations. Her viewpoint may reflect her orientation as an environmental scientist, where research is more quickly incorporated into public policy. As the life sciences increase in their impact this broader view of the social responsibility of scientists is crucial.

Other ethical principles underlying research ethics have been derived from three major areas of responsibility of scientists: those to the employer or client, to third parties, and to other professionals/the profession. Michael Bayles listed six responsibilities to the employer or client: honesty, candor, competence, diligence, loyalty and discretion [5]. The three responsibilities to third parties are truthfulness, nonmaleficence, and fairness. With respect to the profession, scientists should engage in candid and independent research, reform the profession, and promote respect for the profession. Bayles' argument concludes by claiming the ultimate client is the public because they fund the research [5]. A counter view holds that science (knowledge) for science's (knowledge's) sake alone is a primary responsibility.

Which norms are universally subscribed to by scientists?

Little work has been done to test the adoption or practice of norms for scientists. The most specific work designed to test subscription to norms were two national surveys conducted by Melissa Anderson, Karen Seashore Louis and colleagues [3, 4]. These surveys assessed subscription and adherence to the four Merton norms and four Mitroff counter-norms. About 2,000 faculty and doctoral students were surveyed from chemistry, civil engineering, microbiology and sociology departments. Using a scale from 0 to 8 (where 8 is subscription), both faculty and students subscribe more strongly to norms (7.06) than counternorms (4.04). However, both these groups reported seeing others act according to counternorms (5.94) to a higher degree than to norms (4.69).

Another study examined professional values and ethical standards of 385 distinguished natural, technical, and life scientists listed in *Who is Who in Croatia* [19]. The most important standards were conceptual accuracy;

uncompromising commitment to searching for the truth; responsibility for the effects of personal research results; scientific rigor of applied and developmental research (in organizations); avoidance of quick generalizations; support for the excellence of one's scientific institution; and encouragement and introduction of talented students in scientific work. A second tier of professional values held by these scientists were: supporting colleagues; the development and use of knowledge for the benefit of man and society; receptivity to all relevant data, systematism or incorporation of the research findings into the body of knowledge of a scientific field; careful use of one's colleagues' ideas and results; full autonomy in relation to clients; assignment of authorship in congruence with one's contribution; scientific instruction and fair evaluation of students; non-subjectivity in reporting one's results; general logical rigor; accuracy of measuring and mathematical precision; accuracy and clarity of the writing style; non-subjective evaluation of scientific ideas and contribution; a constant scrutiny of all statements and data; replicability of research; open communication; and prohibition of student exploitation. Overall, this group of eminent scientists assigned above-average importance to all the values and norms examined which points to an extraordinary self-expectation of the scientific elite.

Another series of studies paired investigators funded by one branch of the National Science Foundation with regulatory administrators of their institutions [26]. The consensus of the two groups was that the norms of researchers were honesty, integrity, acceptance of responsibility, creativity, working toward the common good (to serve society), and being careful, meticulous, rigorous, objective and logical in one's work. Other norms identified with less concurrence were openness; being disciplined, hard working, willing to share, collaborative, or a good citizen; reporting misconduct; and mentoring and teaching [26]. The conclusion was that scientists endorsed focusing on positive norms and a code of ethics rather than regulations and policies on misconduct.

Philosophies of science

Two philosophical views of science pull it in opposite directions. The first states that gathering knowledge is the sole purpose of science. The second agrees with the value of acquiring knowledge but insists that this must be linked to a focus on the betterment of society. In our autonomy driven society, the acquisition of knowledge for the sake of knowledge alone, translates into a "right" or "ought" justifying all science and promoting limitless research freedom. "What *can* be done" justifies "What *is* done". This philosophy spurs the concept that governmental (societal) restriction of research is paternalistic and results in needless regulatory oversight that impedes scientific advancement. This philosophy unchecked can provide a free pass to justify all means used for research if the experiments are "scientifically" justified. However, if the scientific community is the judge of "scientific soundness," this judgment is inherently blemished by a conflict of interest because the community of science has a vested interest in promoting the industry of science. This can compromise the objectivity of science.

Contrast the first philosophy of science with the Baconian philosophy of science where the acquisition of knowledge must be linked to the betterment of society [8]. This second view positions scientists as servants of society as well as members of the scientific profession, and thereby checks science's hubris. This approach to science asks "What *should* be done?" To justify research, the means must also be ethical.

When pressed, a vast majority of scientists publicly endorse the view that scientific knowledge must be linked to serving humanity, but within the hallowed walls of academia more common statements justify science (knowledge) for science's (knowledge's) sake alone. In fact, the science community often esteems "mavericks" that break convention and societal constraints to make startling discoveries. This does not ignore the fact that concepts of ethical or unethical practice sometimes need to be contemporized in light of new knowledge. But rather than disregarding public sensibilities, appealing that the ends justify the means, or breaking conventions to prove one's case; scientists need to work with society to shape the concepts of ethical practice. Whatever the philosophical view of knowledge, science must be able to justify its endeavors to the broader society and abstain from using unethical means.

What are the essentials of a code?

An ethics code should not be merely endless rules and regulations, which often have a minimalist effect and a negative connotation. Rather, a code of ethics should set forth the aims, principles and virtues to inspire the best ethical practice and character of scientists (Table 1). Reality and ideals are not the same, but like the Hippocratic ideal, a code of ethics for the life sciences can provide a continual standard by which to shape reality towards the ethical practice of science.

Similar to the power relationship between a physician and patient, is the relationship between science and society. A code of ethics for biomedical researchers should: (1) provide guidance for what knowledge should be sought; (2) define the ethical means of acquiring knowledge; (3) emphasize thoughtful examination of potential consequences, both good and bad; and (4) help society prescribe responsible use of the knowledge. Two overarching bioethical principles, beneficence (doing good), and nonmaleficence (judiciously guiding society to anticipate and minimize harms), are embedded in the overarching goal of science. The crucial emphasis of this code is defining the goal for biological and biomedical research, that is, the pursuit of knowledge to advance human health and welfare, and taking responsibility to guide society to minimize negative consequences of this knowledge. While society holds that knowledge acquisition is good, it is equally important to address both the responsibilities of, and boundaries to, the freedom of inquiry granted by society. Society has granted resources and freedom because of the

Table 1 Code of ethics for the life sciences

Goal of science	
The biological and biomedical sciences have the ultimate goal of advancing human health and welfare of all human beings. Scientists and the scientific community accept the responsibility to act on behalf of the interests of all people, and will guide society in the development of safeguards necessary to judiciously anticipate and minimize harms	
Principles for the practice	
Objectivity	Honest assessment and minimization of the biases inherent in science, i.e. cultural and other influences on the experimental design, techniques and interpretation of the data
Questioning certitude	Questioning current authoritative view or dogma in order to continue the process of advancing new knowledge
Research freedom	Allowing ideas to flourish within the scientific community because wrong or true concepts will eventually be proven as such
Research reproducibility	Quality scientific research can be re-proven and is openly available to all qualified scientists to move knowledge forward
Respect for subjects	The highest ethical standards are upheld to respect all living things, with profound respect granted to human life and dignity
Scientific community	The scientific community is the guardian for the integrity of science by proving the veracity of individual findings through peer review and reproducing experimental results, and by training and accrediting future scientists
Virtues	
Duty	Scientists are committed to serve and guard humanity and seek to advance scientific understanding and respect for the truth
Integrity	Scientists strive to be objective, fair, truthful, and accurate
Accountability	Scientists are accountable to their profession and society
Altruism	Scientists' primary focus is the best interests of humanity and not self-interest, commercial interests, or the promotion of the industry of science
Excellence	Scientists are committed to a lifestyle of learning and transmitting knowledge and skills
Respect for colleagues	Scientists treat associates and trainees with respect and credit their contributions

implicit social contract in which science promises to act in society's interests, not its own.

Strategy for developing a code

Medical practice and human subject research is influenced by the Hippocratic tradition; but no similar code of ethics has been formalized for the life and biomedical sciences. While not all scientific societies have explicit codes, it is inaccurate to say that they do not have a code of ethics. The life sciences and biomedical research have an ethos imbedded into scientific practice. The following *Prototype Code of Ethics for the Life Sciences* is an endeavor to articulate the rich ethos existing in the life and biomedical sciences. Formalization of this code of ethics, akin to a Hippocratic standard for the practice of medicine, can provide ideals for management of both internal and external pressures on the practice of science.

This prototype code was constructed to capture the aspiring ethos of science in the spirit of Hippocratic medicine. The Hippocratic tradition ascribes to ethical standards for the goal of medicine (outcomes), the practice of medicine (principles) and the character of physicians (virtues). An appeal to outcomes, principles, and virtues uses two types of ethical theory: (1) moral obligation theories, systems that tell you the right thing to do or the morality of the action itself, and (2) virtue theories, systems that show what kind of person you ought to be or what a moral ''agent'' is. Utilitarian and deontological theories are both moral obligation theories focusing on the morality of the action, but use different methods. In deontological theories the action is inherently considered right or wrong. In contrast, utilitarian theories define the action as right or wrong based on the outcomes.

The *Prototype Code of Ethics for the Life Sciences* is concerned with consequences, defining the overarching purpose of the life sciences as acquiring knowledge for the betterment of mankind. The code also prescribes principles for the practice of ethical science and virtues for scientists. The correct outcome or consequence is important, but the practice is important as well, because if the experiment is not reproducible, then the results are not reliable and the conclusion is worthless for the furthering of science. Equally important are scientists with the virtue of integrity. Different types of ethical theories have strengths and limitations for defining ethical behavior. Focusing on outcomes can promote distributive justice assuring the applicability of science for all mankind, but concern only with an outcome can condone unethical means of acquiring knowledge. Principles for the practice of science assure the reproducibility of science, and gain relevance when science links its activities to the outcome of bettering mankind. Developing scientific virtues is helpful for motivating ethical behavior, but provides little help in decision-making and prescribing the right and wrong actions when principles conflict. Combining these theories allows for a more comprehensive ethical framework for science.

The prototype code was developed by combining outcomes for science, the principles for its practice, and virtues or character values of scientific professionals. Broader definitions of ethical principles for research were sought to provide a basis on which later specific rules may be formulated, criticized and interpreted. The objective, similar to the objective of the Belmont Report for human subject research, is to define the goal of science and identify principles to provide an analytical framework to guide ethical problem solving as new cases arise, rather than proscriptively regulating every foreseeable circumstance. These principles and virtues were identified from the literature and from observations as a scientist. Cultural norms of the life science and bioscience community were identified through codes of ethics from professional societies. Though not all professional societies have published or endorsed codes of ethics within the life sciences, two society's codes, *The Chemist's Code of Conduct* from the American Chemical Society [7] and the *Code of*

Ethics of the American Society for Biochemistry and Molecular Biology's guidelines [2], were incorporated into the prototype code. A literature review identified additional recognized principles for the practice of science [8, 21]. The *Project Professionalism* of the American Board of Internal Medicine served as a template of virtues or character aspirations for scientists [1]. A further element was incorporated into the prototype code defining the overarching purpose or goal and responsibilities of scientific activity. The prototype code then was critiqued by several ethicists and practicing scientists (see Acknowledgements).

Prototype code of ethics for the life sciences

The goal of the life sciences

The goal of life science research is the pursuit of knowledge in the biological and biomedical sciences with the ultimate goal of advancing the health and welfare of all human beings. This pursuit should respect human life and dignity, remembering that science is a tool, a means to an end and never an end in itself. Underlying the freedom granted by society to pursue knowledge in the life sciences is trust in the integrity of scientists and the practice of science. In granting the privilege of freedom of inquiry, society implicitly assumes that scientists act with integrity on behalf of the interests of all people. Scientists and the scientific community should accept the responsibility for the consequences of their work by guiding society in the development of safeguards necessary to judiciously anticipate and minimize harms.

Principles of the practice of science

Objectivity

The *prima facie* principle for the practice of science is objectivity. Objectivity is dealing with facts without distortion by personal feelings, prejudices or interpretations. The principle of objectivity is embedded in the ability to accept data that disproves a theory or hypothesis as readily as data that supports a theory or hypothesis. Scientists should strive to be objective in the experimental design, analysis, and conclusions of their work while at the same time recognizing that the very process of observation and interpretation of facts is a human and social venture and true objectivity is impossible. Scientists should also endeavor to recognize the limitations of their methods and be sensitive to the bias inherent in scientific activity. In addition, scientists should be aware of biases introduced by external social and philosophical influences on the activity of science, and should be open and honest about their relationships, (e.g., relationships involving their employer and/or funding mechanisms for the research), their commercial interests, and the philosophical or political implications of the research, as these all can potentially influence the objectivity of scientists.

Questioning certitude

Questioning certitude is the readiness to question the current authoritative view or dogma in order to continue the process of advancing new knowledge. This principle asserts that no theory or fact is sacred; rather, experiments and conclusions should be continually re-evaluated in light of further discovery. The principle of questioning certitude helps to minimize bias in knowledge uncovered by any one study or field of study and acknowledges that there are inherent limitations of knowledge for scientific inquiry and interpretation.

Research freedom

Research freedom allows ideas to flourish within the scientific community with the understanding that eventually wrong concepts will be proven as such. Placing too much restriction on new ideas may prevent advances in knowledge, so a large amount of freedom is granted within the community of science. However, promoting untested hypotheses or ideas as fact or as conventional scientific wisdom within the public domain is prohibited. Research freedom is not limitless; the practice of science does not condone unethical means of moving knowledge forward.

Research reproducibility

Quality scientific research should be able to be re-proven and to provide the groundwork for further exploration by any qualified scientist. Scientists should value the principle of open research to maximize the advancement of knowledge and should conduct their research in a way that allows open and thorough evaluation as well as enabling repetition. When scientists are given privileged communication of research findings prior to their public distribution (e.g., for purposes of evaluation for publication or funding), this knowledge must be kept as a sacred trust and not used until public distribution.

Respect for subjects

Scientists should uphold the highest ethical standards that respect all living things, with profound respect granted to human life and dignity. Respect entails designing experiments with the least invasive and destructive methods possible and avoiding unnecessary duplication of experiments. Respect necessitates designing experiments to answer the most pressing problems of humanity with stewardship towards limited resources.

The highest ethical standards for human subject research are codified in the Nuremberg Code (1946–1949) [24], the Belmont Report (1979) [23] and the Declaration of Helsinki (1964, 2000) [27, 28]. The duty of scientists includes protection of life, health, privacy and dignity of research subjects. The scientific question must be of significant importance for human welfare and health and the well being of the subject must take precedence over the interests of science and society. Human subject research should, when possible, have prior animal experimentation showing a promising result with minimized risk and no other methods available for the same end. The risk should not be greater than the humanitarian importance of the problem to be solved, and no human experiments are allowed with an a priori reason to expect death. The knowledge gained from the research should benefit all populations in which the research is performed and no segment of the population should be excluded or bear the brunt of the experimentation.

Animal experimentation should have a peer-reviewed scientific rationale for the purpose and proposed use, justification of the species and number needed, and assurances that there are no other less-invasive or non-animal alternatives to answer the experimental question. Scientists should be responsible for the welfare of animals and organisms and minimize suffering and harm to animals by using appropriate sedation, analgesia and anesthesia and timely intervention to euthanatize suffering animals.

Community of science

Science is a process carried out by an interacting community of scientists. This community has been given an authoritative voice by society for esoteric knowledge in the domain of biological and biomedical sciences, and the skills thereof. With this authority, it bears responsibility as the guardian for the integrity of science. While each individual member has been given freedom to pursue knowledge, the scientific community has the obligation to provide the normative processes for research activity through peer evaluation. The scientific community should provide proof of the veracity of individual findings through peer review and reproducing experimental results. Moreover, the community should afford a stamp of reliability only when other members of the community can reconfirm the research. The scientific community should also contextualize individual studies and provide assurances of the accuracy, the scope of the finding, and candid assessment of potential biases, conflicts of interests, and uncertainty of the knowledge. The community has an obligation to correct inflation of an individual study's conclusions, misrepresentation of conventional scientific wisdom, or misuse of knowledge beyond its appropriate application. The scientific community also has an obligation to rebuke fraud.

In addition, the scientific community has the responsibility for training and accrediting future scientists in the practice of science. Students of science should be trained in both the knowledge and the philosophy of scientific practice.

Virtues of the scientist

Duty

Scientists should recognize the special status afforded to them by society as authorities on esoteric knowledge in the domain of biological and biomedical sciences. They are considered agents seeking to uncover empirical objective knowledge or ‘‘truth’’ in this sphere. As such, they should commit themselves to serve and guard humanity, including its individual members. Life scientists should accurately communicate their science and educate the public regarding current understanding and uncertainty within their sphere of knowledge, seek to advance scientific understanding within and beyond the scientific community, and respect the truth.

Integrity

Scientists should strive to be objective, fair, truthful, and accurate. They should speak publicly as authorities only about areas in which they have expertise. Integrity demands that research results are reported with as much objectivity as possible and with no deliberate bias. Scientists should strive to present research in such a way as to avoid its possible misuse and misapplication.

Accountability

Scientists are accountable to their profession and to society. They have a duty to participate in the community of science, in part, in order to ensure that their scientific contributions, and those of their collaborators, are thorough, accurate, and unbiased in design, implementation, and presentation. Scientists are accountable for their public comments on scientific matters, which should be made with care and precision and devoid of unsubstantiated, exaggerated, or premature statements. They should seek to understand, anticipate and be forthcoming about the potential consequences (both benefits and harms) of their work.

Altruism

The scientist’s primary focus should be on the best interests of humanity and not self-interest, commercial interests or the promotion of the industry of science. Care must be taken to assure that personal ambition and aspirations, or the desire to acquire profit or notoriety, does not influence professional scientific judgment. Scientists are obligated to be forthcoming with potential relationships and biases that may pose a conflict of interest or influence their objectivity. The community of science provides the normative processes to ensure that personal ambition or potential conflicts of interest do not influence the objectivity of reviewed research.

Excellence

Scientist should be committed to a lifestyle of learning and should remain current with developments in their field. They are committed to readily transmit their knowledge and skills to the community of science and future generations of scientists. Scientists should keep accurate and complete laboratory records to enhance the activities of the community of science in order to confirm the veracity of individual findings through peer review and reproducing experimental results.

Respect

Scientists should treat associates and trainees with respect, regardless of the level of their formal education, encourage them, learn with them, share ideas honestly, and give credit for their contributions. They should credit colleagues, sources, and published work for inspiration of their ideas. Scientists have responsibility for the health and welfare of their employees and trainees so they should seek to minimize any potential risks in their laboratory work, and inform their employees and trainees of these risks.

Conclusion

The time is ripe for scientific communities to reinvigorate professionalism and define the basis of their social contracts. Codifying the social contract between science and society is a crucial step in sustaining public trust in the scientific enterprise. Appeals to the ideology of science and blind trust will no longer suffice. If scientific communities continue to avoid practicing professionalism and ‘‘self-regulation’’, Congress will be forced to act (regulate) on behalf of society.

How can the scientific communities take up the standard? Societies can begin with commissioning committees to draft and implement their codes of ethics that are responsive to externally and internally applied pressures that are influencing their practice of science. This *Prototype Code of Ethics for the Life Sciences* is presented to help frame those discussions. However, adopting a code of ethics is merely the beginning. Further work is essential to not only translate the codes of ethics into codes of conduct, but societies must design systems to enforce these codes. ‘‘‘Self-regulation’ requires not only the specification of norms but also the evaluation of conduct and, when necessary, the imposition of sanctions’’ [26] (p. 378). Most importantly reinvigorating professionalism will require adopting these norms as ‘‘The Practice of Science’’. No longer should scientific professionalism discussions be relegated to educational sub-points or special interest conferences. Explicit discourse on these ideals, principles, and virtues should be part of the heart and soul practices of both laboratories and scientific communities. The communities of science must rise to the challenge and clarify their social contracts, articulate professional conduct and responsibility for their members, and practice "self-regulation" or they will have no grounds for complaining when the government steps in.

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References

1. ABIM Committee on Evaluation of Clinical Competence. (1995). *Project professionalism*. Philadelphia, PA: American Board of Internal Medicine. *http://www.abim.org/pdf/profess.pdf*.
2. American Society for Biochemistry and Molecular Biology. (1998). *Code of ethics*. Bethesda, MD: American Society for Biochemistry and Molecular Biology. *http://www.asbmb.org/asbmb/site.nsf/Sub/CodeofEthics?opendocument*.
3. Anderson, M. S., & Louis, K. S. (1994). The graduate student experience and subscription to the norms of science. *Research in Higher Education, 35*, 273–299.
4. Anderson, M. S. (2000). Normative orientations of university faculty and doctoral students. *Science and Engineering Ethics, 6*, 443–461. Discussion 463–465.
5. Bayles, M. D. (1981). *Professional ethics*. Belmont: Wadsworth Pub. Co.
6. Cohen, J. J. (2001). Trust us to make a difference: Ensuring public confidence in the integrity of clinical research. *Academic Medicine, 76*, 209–214.
7. Council Committee on Professional Relations. (1994). *The chemist's code of conduct*. The American Chemical Society. http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=membership%5Cconduct.html.
8. Cournand, A. (1977). The code of the scientist and its relationship to ethics. *Science 198*, 699–705.
9. Edsall, J. T. (1975). *Scientific freedom and responsibility*. Washington, DC: AAAS Committee on Scientific Freedom and Responsibility, American Association for the Advancement of Science.
10. Frankel, M. S. (1994). Ethics in research: Current issues for dental researchers and their professional society. *Journal of Dental Research*, *73*, 1759–1765.
11. Frankel, M. S. (2000). Scientific societies as sentinels of responsible research conduct. *Proceedings Society of Experimental Biology and Medicine, 224*, 216–219.
12. Frankel, M. S., & Bird, S. J. (2003). The role of scientific societies in promoting research integrity. *Science and Engineering Ethics,* 9, 139–140.
13. Heitman, E. (2000). Ethical values in the education of biomedical researchers. *Hastings Center Report, 30*, S40–S44.
14. Korenman, S. G., Berk, R., Wenger, N. S., & Lew, V. (1998). Evaluation of the research norms of scientists and administrators responsible for academic research integrity. *Journal of American Medical Association, 279*, 41–47.
15. McCabe, D. L., & Trevino, L. K. (1993). Academic dishonesty: Honor codes and other contextual influences. *Journal of Higher Education, 64*, 522–538.
16. Merton, R. K. (1973). *The sociology of science*. Chicago: University of Chicago Press.
17. Mitroff, I. (1974). Norms and counter-norms in a select group of the Apollo moon scientists: A case study of the ambivalence of scientists. *American Sociological Review, 39*, 579–595.

18. National Science Advisory Board for Biosecurity. (2006). *Considerations in developing a code of conduct for dual use research in the life sciences*. Bethesda, MD: National Institutes of Health. http://www.biosecurityboard.gov/pdf/NSABB%20Draft%20Guidance%20Documents.pdf.
19. Prpic, K. (1998). Science ethics: A study of eminent scientists' professional values. *Scientometrics, 43*, 269–298.
20. Reiser, S. J., & Bulger, R. E. (1997). The social responsibilities of biological scientists. *Science and Engineering Ethics, 3*, 137–143.
21. Shrader-Frechette, K. (1994). *Ethics of scientific research*. Maryland: Rowman & Littlefield Publishers, Inc., Lanham.
22. Somerville, M. A., & Atlas, R. M. (2005). Ethics: A weapon to counter bioterrorism. *Science, 307*, 1881–1882.
23. The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research. (1979). *The belmont report*. Washington, DC: Department of Health, Education, and Welfare. *http://www.hhs.gov/ohrp/humansubjects/guidance/belmont.htm*.
24. Trials of War Criminals before the Nuremberg Military Tribunals. (1949). *The nuremberg code*. Washington, DC: US Government Printing Office. *http://www.hhs.gov/ohrp/references/nurcode.htm*.
25. US Office of Research Integrity. (2000). *The role and activities of scientific societies in promoting research integrity*. Washington, DC: American Association for the Advancement of Science. http://www.aaas.org/spp/sfrl/projects/report.pdf.
26. Wenger, N. S., Korenman, S. G., Berk, R., & Berry, S. (1997). The ethics of scientific research: An analysis of focus groups of scientists and institutional representatives. *Journal of Investigational Medicine, 45*, 371–380.
27. World Medical Association. (1964). *Declaration of Helsinki*. Finland, Helsinki: World Medical Association.
28. World Medical Association. (2000). *Declaration of Helsinki*. Finland, Helsinki: World Medical Association.