Ethics assessment in different fields

Natural Sciences

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Annex 2.a
Ethical Assessment of Research and Innovation: A Comparative Analysis of Practices and Institutions in the EU and selected other countries
Deliverable 1.1

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Contents

1 Introduction

This report tackles ethical values and issues and their institutionalisation in the natural sciences. The focus here is on chemistry and physics, with some mention of the earth sciences. Biology, medical sciences and emerging technologies are excluded as they are the subject of other SATORI reports. This also entails that human subjects research issues are given less attention here. More consideration is therefore given to issues concerning scientific integrity and societal responsibility

1.1 Nature and scope of the field

Natural sciences study the physical world using systematic scientific methods of observation, hypothesis, measurement and experimenting, and evaluation, combined with the use of statistics, to confirm or refute hypotheses. The main natural sciences include chemistry, physics, biology and earth sciences.

National Science Education Standards give the following characterisation of natural sciences:

Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Although all scientific ideas are tentative and subject to change and improvement in principle, for most major ideas in science, there is much experimental and observational confirmation. Those ideas are not likely to change greatly in the future. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations[1].

Chemistry is "the study of the properties and behaviour of matter."[2] There are several ways to divide the science into branches, namely organic and inorganic, analytic and synthetic, biochemistry and physical chemistry. Chemistry has potential ethical implications since it "is closely involved in society, providing the foundations for areas of applied science such as nutrition, medicine, environment, energy and materials".[3]

Physics also involves the study of matter, but from the perspective of forces, motion, energy, waves, particles etc. While chemistry "focuses on how substances interact with each other and with energy", physics is concerned with basic principles of matter and energy "from a very large scale (the entire universe) down to a very small scale (subatomic particles)".[4] Branches of physics include astrophysics, particle physics, atomic, molecular and optical physics etc.

Earth sciences involve the study of the planet Earth by physical investigations of lithosphere, hydrosphere, atmosphere and biosphere.[5] The main branches are geology, hydrology, oceanography, ecology, climatology, meteorology, among many others. Earth sciences embrace the same ideals of scientific method in natural sciences as do chemistry and physics, with one substantial difference. The latter two can, to a large extent, conduct controlled

[1] *National Science Education Standards (NSES),* National Academy Press, Washington, D.C., 1996, p. 171.
[2] Brown, Theodore E., Eugene H. LeMay, Bruce E. Bursten, Catherine Murphy, Patrick Woodward, *Chemistry: The Central Science*, Pearson, Harlow 2011, p. 16.
[3] Noyori, Ryoji, and Joe P. Richmond, "Ethical Conduct in Chemical Research and Publishing", *Advanced Synthesis & Catalysis*, 2013, 355 (1), p. 3.
[4] http://en.wikipedia.org/wiki/Comparison_of_chemistry_and_physics
[5] http://en.wikipedia.org/wiki/Earth_science

experiments, which can be repeated. In earth sciences, controlled experiments are difficult to achieve due to the unlimited number of variables involved that cannot be simply replicated in the lab. Geologists, for example, cannot directly test their hypotheses, but need to rely on circumstantial evidence (e.g., collecting data on specimens).

1.2 Types of ethical issues in the field

The general scientific principles and activities common to all areas of natural sciences also comprise the sources of issues that fall under the scrutiny of ethical assessment. These scientific principles include observation, measurement, objective analysis, the testing of hypotheses through experimentation, replication of findings, peer review through public lectures and published works. Additionally, researchers and scientists have strong ethical obligations to society and environment, and should act in the public's interests by conducting responsible research and promoting discussions on science related issues. Safety is a major ethical concern in natural sciences and engineering, much more so than in social sciences or humanities, and underlines the technical standards and codes of ethics. Furthermore, individual judgment is a fundamental aspect of all scientific practice and a first step towards handling scientific misconduct. As many areas of natural sciences have a substantial effect on the environment and society, the ethical decision-making covers a broad range of responsibilities, and puts a strong emphasis on the following categories of scientific misconduct:

- *plagiarism* and *improper authorship*;
- *falsification of data* (e.g., data fabrication, selective reporting of findings);
- *misappropriation of the ideas* of others;
- *non-disclosure of information*, which can have harmful side effects (e.g. laboratory trials);
- *misrepresentation of scientific experiments, funds or other resources* (e.g. for personal/career gain);
- *misrepresentation of qualifications, experience, or research accomplishments* (e.g., to obtain research programmes, external funding, professional career advancement);
- *violations involving the use of funds, care of animals, human subjects, or radioactive, biologic, or chemical materials*;
- *the violation of generally accepted research practices* in carrying out research (e.g. manipulation of experiments to get desired results, statistical or analytical manipulation of results, improper reporting of results).

1.3 Historical overview

Most ethical issues discussed in the natural sciences relate to the challenges of professional ethics, with scientific integrity cited as one of the most important aspects of natural science research, both from the perspective of advancement and promotion of science, as well as from the perspective of social responsibility. In this overview, we address the fundamental

component of natural sciences, *the scientific method*, which sets the foundation for later discussion of contemporary ethical issues and challenges in natural sciences. It is important to note that many areas of the natural sciences involve both specialized techniques, found only within certain sub-branches, as well as general methodological principles that are shared by all. These are expressed through general principles of the scientific method, which begins with observations about the natural world, hypothesis generation and testing through experiments based on empirical data. The Oxford English Dictionary defines the scientific method as "a method or procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses."

In 1637, Descartes made a first attempt at defining scientific method in his "*Discourse on the Method"*. A year later, Galileo set two thought experiments, intended to disprove existing physical theories, and in 1650 the first learned society, the Royal Society, was established. *Experimental evidence* became the main arbiter of truth and *repeatability* an important evaluation criteria[6]. Fifteen years later, the first scholarly journal was established in 1665, in 1675 the peer review method, and in 1687 Newton devised the scientific concepts of *hypothesis* and *prediction*. The 18th and 19th centuries witnessed a number of developments. Hume published "*Treatise on Human Nature"*, Bayes published the basis for Bayesian inference, and Pierce the *Illustrations of the Logic of Science.* At the end of 19th century, Chamberlin proposed the use of multiple hypotheses to assist in the design of experiments[7]. The 20th and 21st centuries witnessed the development of experiment design procedures (Fisher) and the *double blind experiment*[8]. Popper defined *falsifiability*[9] as the criterion for evaluating new hypotheses, Kuhn introduced the concept of *paradigm shift* in the study of scientific method, and Platt introduced *strong inference*[10] as a model of scientific inquiry. Adam became the "first working prototype of a "robot scientist" able to perform independent experiments to test hypotheses and interpret findings without human guidance".[11] The development and elaboration of rules for scientific reasoning and investigation is ongoing.

In the following sections, the report offers a discussion of ethics related activities in the natural sciences, focusing on physics and chemistry. Section 2 offers a discussion of the major principles of ethics assessment by presenting ethical values characteristic for the respective scientific field. Section 3 describes ethical issues in the natural sciences, while Sections 4 and 5 offer a discussion of legislative aspects through national and international institutionalisations. Section 6 provides a summary of the results of report.

This report is based on the analysis of various sources. Online resources (websites) were used for gathering general information on national and international associations, legislative bodies and levels of institutionalisation. Ethics assessment reports, guidelines, professional standards, codes of ethics and codes of conduct, as well as conference proceedings and scientific publications (articles, books, journals) were used to get more in-depth knowledge of the role

[6] http://en.wikipedia.org/wiki/Timeline_of_the_history_of_scientific_method
[7] Ibid.
[8] http://en.wikipedia.org/wiki/Blind_experiment
[9] http://en.wikipedia.org/wiki/Falsifiability
[10] http://en.wikipedia.org/wiki/Strong_inference
[11] http://en.wikipedia.org/wiki/Robot_Scientist

of ethics in respective fields. Existing SATORI documentation (e.g. scientific discipline reports, country reports, quickscan documents) and interviews with experts and representatives of major stakeholders in areas of ethics and ethics assessment were also used in the report.

2 Ethical Assessment: Approaches and Principles

Ethical assessment in the natural sciences mostly deals with issues in areas of academic/research and professional ethics, and is characterised by the following categories of major ethical principles: *scientific honesty*, *intellectual freedom* and *openness*, the *principle of credit* and the *principle of care and social responsibility* (e.g., communication, safety and respect for the environment). Furthermore, the practice of *experimental control* and *reproducibility of results* is a fundamental aspect of establishing reliable scientific practice and credibility of results. The abovementioned ethical principles draw from more general principles, and are not limited to the domain of science. For example, physics and chemistry are continuously used in the wider world and decision-making typically also involves ethical choices of other stakeholders outside the domain of science and scientific professions, e.g. those of politicians/policy makers, economists and general public/consumers. Similarly, in the earth sciences, much focus in the last decades has been on climate change and global warming observations, the impact of regional variations on natural systems (of wildlife, marine systems, ice layers, and the timing of vegetation lifecycles), and the ways in which these changes have substantially accelerated during the twenty-first century. The amount of uncertainty in making informed conclusions is reflected in variations in results from research studies on these issues. Most reports related to policy making centre on assumptions regarding economic growth, technological developments, and population growth, which are arguably the three most critical variables affecting the uncertainty over future climate change and policy options[12].

Apart from professional codes of conduct that have a more established tradition, ethical discussions in the fields of chemistry and physics have become more frequent at the end of the 20th century. For example, when *HYLE: International Journal for Philosophy of Chemistry* published a special issue on the ethics of chemistry in 2001, the journal's editor claimed the following:

To be sure, many philosophers are aware of moral issues related to chemistry, such as chemical weapons research, environmental pollution, chemical accidents, unintended bad 'side-effects' of chemical products, etc. However, […] philosophers seem to be unable to relate these issues to chemistry. Instead, they discuss them in diverse fields such as warfare ethics, environmental ethics, medical ethics, or ethics of technology, without recognizing the common grounds of chemistry.[13]

The two special editions of *HYLE* tried to open the debate with papers discussing values in chemical research, such as the relation between the advancement of science and its societal

[12] http://stephenschneider.stanford.edu/Climate/Climate_Policy/Policy.html
[13] Schummer, Joachim, "Ethics of Chemical Synthesis", *HYLE: International Journal for Philosophy of Chemistry*, 2001, 7 (2), p. 103.

responsibility.[14] In one of these issues, a paper compared the professional codes of ethics of chemists and engineers and came to the conclusion that the basic value for chemists is "usefulness", while engineers set "a higher standard" by their concern for "the *enhancement* of human welfare".[15] In a collective essay, composed of contributions to the symposium "Ethics, Chemistry and Education for the Environment", organised by the European Association for Chemical and Molecular Sciences (EuCheMS) in 2010, the authors stress sustainability as a key ethical value to be followed by chemical science, in addition to the importance of its integration in chemical education.[16]

The American Physical Society was still very confident in its compliance with ethical standards in 1987:

> The physics community has traditionally enjoyed a well-deserved reputation for maintenance of high ethical standards and integrity in its scientific activities. Indeed, the American Physical Society is one of the few professional societies which has not felt the need for a formal code of ethics.[17]

The debate on ethics was only put on the agenda following some high-profile cases of misconduct.[18]

Concerns about scientific integrity and research ethics in general are the domain of the major professional and scientific associations. These organisations often formulate professional codes of conduct and ethical guidelines for scientific publications. University departments or regional organisations often refer to general ethical guidelines of their universities or the national or international organisations with which they are associated. As specific ethical frameworks for these disciplines are not very well developed, researchers and organisations sometimes feel the need refer to more general ethical frameworks developed by organisations such as the IAP – the global network of science academies (*Responsible Conduct in the Global Research Enterprise*[19]) or the US National Academy of Sciences (*On being a scientist*[20]).[21]

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[14] *Cf*. Del Re, Giuseppe, "Ethics and Science", *HYLE: International Journal for Philosophy of Chemistry*, 2001, 7 (2), pp. 85-102; Laszlo, Pierre, "Handling Proliferation", *HYLE: International Journal for Philosophy of Chemistry*, 7 (2), pp. 125-140.
[15] Davis, Michael, "Do the Professional Ethics of Chemists and Engineers Differ?", *HYLE: International Journal for Philosophy of Chemistry*, 2002, 8 (1), p. 29.
[16] Hartmut, Frank, Luigi Campanella, Francesco Dondi, Jan Mehlich, Erich Leitner, Giuseppe Rossi, Karine Ndjoko Ioset, Gerhard Bringmann, "Ethics, Chemistry, and Education for Sustainability", *Angewandte Chemie (International Edition)*, 2011, 50 (37), pp. 8482–8490.
[17] Quoted in Kirby, Kate and Frances A. Houle, "Ethics and the welfare of the physics profession", *Physics Today*, 2004, 57 (11), p. 42.
[18] *Ibid*.
[19] InterAcademy Council and IAP – the global network of science academies, *Responsible Conduct in the Global Research Enterprise*, Policy Report, September 2012.
[20] National Academy of Sciences, *On Being a Scientist: Responsible Conduct in Research*, National Academy Press, Washington 2014.
[21] For these references *cf*. Noyori and Richmond, op. cit, 2013, p. 3; Hammes, Gordon G., "Ethics in Scientific Publication", in A. Coghill et al (eds.), *The ACS Style Guide*, American Chemical Society, Washington, DC, 2006, p. 4; University of Oxford. *Welcome to Chemistry: Department of Chemistry Graduate Handbook 2013/14*, p. 27. http://www.chem.ox.ac.uk/graduatestudies/Graduate%20Handbook%202013%20_final.pdf

The American Chemical Society declared its concern for ethical conduct already in its 1937 *Charter*: among its objectives is "the improvement of the qualifications and usefulness of chemists through high standards of professional ethics, education and attainments".[22] The latest document that reflects this concern is the 2012 revision of *The Chemical Professional's Code of Conduct*. This document acknowledges responsibilities of the chemist towards the public (serving public interest and safety), the science of chemistry (advancement of science, respect for truth), the profession ("remain current with developments in their field, share ideas and information, keep accurate and complete laboratory records, maintain integrity in all conduct and publications, and give due credit to the contributions of others"), the employer ("perform work honestly, competently, comply with safety policies and procedures"), employees, students, colleagues, clients and the environment ("responsibility to understand the health, safety and environmental impacts of their work, to recognise the constraints of limited resources, and to develop sustainable products").[23]

The UK's Royal Society of Chemistry has its own *Regulation of the profession and code of conduct*, which sets out a number of responsibilities concerning employees, employers, presenting legal evidence, compliance with relevant legislation, expressing professional opinions in public etc.[24] In terms of research ethics it emphasises serving the public interest. The RSC expects members to use their professional skills to:

- Advance the welfare of society, particularly in the fields of health, safety and the environment.
- Advocate suitable precautions against possible harmful side-effects of science and technology.[25]

The American Physical Society's *Guidelines for Professional Conduct* state as their highest value the responsibility for the welfare of the community of science.[26] The document deals with responsibilities concerning the presentation of research results, publication and authorship practices, peer review and conflict of interest. The APS has also prepared educational material on ethics for students, where integrity and honesty are stated as the main values of research.[27]

"Standards of ethical conduct for publications in chemistry have been elaborated by major societies, such as the American Chemical Society (ACS) and the European Association for Chemical and Molecular Sciences (EuCheMS)."[28] Documents prepared by both institutions include very similar values and principles. The introduction to the EuCheMS *Ethical Guidelines for Publication in Journals and Reviews* states that such codes are necessary to

[22] American Chemical Society, *The Chemical Professional's Code of Conduct*, http://www.acs.org/content/acs/en/careers/career-services/ethics/the-chemical-professionals-code-of-conduct.html
[23] *Ibid*.
[24] Royal Society of Chemistry, *Regulation of the profession and code of conduct*, http://www.rsc.org/images/code-of-conduct_tcm18-5101.pdf
[25] *Ibid*., p. 9.
[26] American Physical Society, *Guidelines for Professional Conduct*, http://www.aps.org/policy/statements/02_2.cfm
[27] Doss, Heide, and Gabriel Popkin (eds.), *Ethics Case Studies – Teacher Edition*, Case studies developed by the APS Task Force on Ethics Education, p 1. http://www.aps.org/programs/education/ethics/upload/Ethics-Case-Studies-Teacher-Edition.pdf
[28] Noyori and Richmond, op. cit., 2013, p. 4.

"maximise the benefits of science to society and the profession".[29] The basic value of scientific publication is "sharing of knowledge, even though this may sometimes forego any immediate personal advantage". Serving the profession and society and sharing of knowledge is also to be found in the ACS' *Ethical Guidelines to Publication of Chemical Research*.[30] Both documents define responsibilities for editors, authors and referees; however, the ACS version adds "obligations of scientists publishing outside the scientific literature". Both sets of guidelines are based on principles such as confidentiality, fairness, honesty (in data presentation) and exclusion of bias and conflict of interest and warn against plagiarism, data falsification, duplicate publications, etc. According to both *Guidelines*, research involving human subjects or live animal testing requires a statement outlining compliance with relevant laws and guidelines. (The Royal Society of Chemistry has adopted the ACS *Guidelines*.)

Several leading chemical departments from universities around Europe (with the support of EuCheMS) have formed the Ethics & Science for the Environment Forum that brings together scientists from different fields to debate on sustainable development, research ethics and similar topics.[31] Often, research institutions also have their own codes of conduct which are typically more detailed variations of internationally adopted ethical principles within the specific scientific field, but tailored to the mission and culture of the specific organisation. For example, the CERN (European Organization for Nuclear Research) code lists integrity, commitment, professionalism, creativity and diversity as its basic values.[32]

3 Overview of Ethical issues

As in other research fields, plagiarism is a problem in natural sciences.[33] Among issues of *scientific integrity*, data falsification or fabrication is another major problem with some high profile cases of misconduct being reported.[34] The University of Oxford's "Graduate Handbook" for chemistry students describes the former type of misconduct as follows: "In the worst instances this can be complete fabrication of data subsequently claimed as experimental results, or the deliberate changing of data to support your hypothesis. Such practices are very serious because they can mislead other researchers into following false leads."[35] Since experiments are crucial for natural sciences, exact reporting of their results is key to the

[29] *Cf*. EuCheMS the European Association for Chemical and Molecular Sciences, *Ethical Guidelines for Publication in Journals and Reviews*, 2006. http://www.euchems.eu/fileadmin/user_upload/binaries/Ethicalguidelines_tcm23-54057.pdf.)
[30] *Cf*. American Chemical Society, *Ethical Guidelines to Publication of Chemical Research*, 2014. http://pubs.acs.org/userimages/ContentEditor/1218054468605/ethics.pdf
[31] http://www.cheesefondue-workshops.uni-bayreuth.de/CFW09/fora.html
[32] CERN Code of Conduct, http://cds.cern.ch/record/1273755/files/Codeofconduct.pdf
[33] For a plagiarism case in chemistry, see the case of Leo A. Paquette of Ohio State University; *cf*. Zurer, Pamela, "NSF, Paquette Settle Misconduct Case", *Chemical and Engineering News*, 1998, 76 (10), p. 25. http://pubs.acs.org/doi/abs/10.1021/cen-v076n010.p025
[34] For a well-documented data falsification and fabrication case in chemistry, see the case of Bengü Sezen at Columbia University; *cf*. Schulz, William G., "Reports Detail A Massive Case Of Fraud", *Chemical and Engineeering News*, 2011, 89 (28), p. 4. https://pubs.acs.org/cen/news/89/i28/8928notw1.html. A comparable incident in physics was the high-profile case of Jan Hendrik Schön; *cf*. Reich, Eugenie Samuel, *Plastic Fantastic: How the Biggest Fraud in Physics Shook the Scientific World*, Palgrave Macmillan, New York 2009.
[35] University of Oxford, *Welcome to Chemistry: Department of Chemistry Graduate Handbook 2013/14*, op. cit., p. 27.

integrity of scientists and institutions. Misconduct "is hard to detect in a manuscript and is usually discovered only after publication, if at all";[36] while peer reviewers of articles can request additional experiments, "there is no way they can be expected to assess whether the data itself is real or not".[37] Frauds are usually exposed when other scientists are unable to reproduce the results: "physically and independently recreating an experiment remains the best way to validate data".[38] Some authors emphasise that beyond the blatant cases of misconduct, there is a grey area between legitimate and illegitimate treatment of data. A still often discussed example from the history of physics is Robert Millikan's oil drop experiment which eliminated a part of the data from consideration. In literature on the topic, the experiment "appears as a case of 'good scientific judgment' on the one hand, and scientific misconduct on the other".[39]

The treatment of data is very important in potentially controversial topics such as climate change, which is studied in some of the earth sciences. The Intergovernmental Panel on Climate Change (IPCC) (even though it does not formulate specific ethical guidelines) is careful to make the assessment process for its reports as transparent as possible while also imposing a conflict of interest policy.[40] Discussions on climate change show the complexity of the relationship between science, ethics and climate policy, especially with regard to the assessment of ecological and economic impacts of human-induced climate change, and the need to create viable climate policies and technological solutions. Schneider highlights the pervasive issue of the *double ethical bind* with which scientists are confronted:

> On the one hand, as scientists we are ethically bound to the scientific method, in effect promising to tell the truth, the whole truth, and nothing but – which means that we must include all doubts, the caveats, the ifs, ands and buts. On the other hand, we are not just scientists but human beings as well. And like most people we'd like to see the world a better place, which in this context translates into our working to reduce the risk of potentially disastrous climate change. To do that we need to get some broad based support, to capture the public's imagination. That, of course, means getting loads of media coverage. So we have to offer up scary scenarios, make simplified, dramatic statements, and make little mention of any doubts we might have. This 'double ethical bind' we frequently find ourselves in cannot be solved by any formula. Each of us has to decide what the right balance is between being effective and being honest. I hope that means being both.[41]

Due to the links between chemical research and chemical industry, issues of conflict of interest may arise: "These concerns involve the funding of academic research by private corporations; the increasing pressure, both internal and external, on university scientists to patent and commercialize the results of their research; and the large-scale privatization of

[36] Noyori and Richmond, op. cit., 2013, 355 (1), p. 5.
[37] "They did a bad bad thing", (unsigned editorial), *Nature Chemistry*, 2011, 3 (5), p. 337.
[38] *Ibid*.
[39] Segerstråle, Ullica, "Good to the last drop? Millikan stories as 'canned' pedagogy", *Science and Engineering Ethics*, 1995, 1 (3), p. 197.
[40] *Cf*. http://www.ipcc.ch/organization/organization_review.shtml, http://www.ipcc.ch/pdf/ipcc-principles/ipcc-conflict-of-interest.pdf
[41] Schneider, S. H., 1989. http://stephenschneider.stanford.edu/Publications/PDF Papers/DetroitNews.pdf

knowledge in commercial databases."[42] Several documents on research ethics in natural sciences emphasise these problems.[43]

Another group of ethical issues in natural sciences falls under the umbrella of *responsibility towards society*. Defining responsibility is a particularly complicated issue as new theories and inventions can have potential further developments and uses that are sometimes very hard to predict and are out of the scope of influence of the initial researcher. The most famous examples in the history of natural sciences include Alfred Nobel's invention of dynamite and his subsequent regrets and the use of nuclear physics for the production of nuclear weapons. As Hartmut et al. state "[s]ometimes the original purpose of a process or a substance may be lost and other applications are adopted that are completely different from the original intention, sometimes with catastrophic consequences."[44] In chemical science, in which approximately 900,000 new substances are published every year,[45] there is an on-going debate about the extent to which "chemists, as free creators of new substances, are generally responsible for all possible harms caused by their creations".[46] Some researchers argue that "conventional risk assessment might not be enough when dealing with new compounds"[47] and that it should be supplemented by an ethical framework. Jacob and Walter (2005) illustrate this point with the case of Agent Orange, a chemical that was first published in a scientific journal, then used as herbicide that caused environmental pollution and finally used as a chemical weapon by the US army in the Vietnam War.

Some authors have questioned the ethics of researchers who choose to work for the weapons industry: "since it is justified to hold chemists, as anybody else, responsible to humanity, every chemist involved in such projects as chemical weapons research violates norms of general morality".[48] One analysis of chemists' codes of ethics has shown that chemists "are under no *professional* obligation to refuse work that 'might be used for ill'".[49] This line of reasoning can be extended to the sometimes questionable practices of chemical industry: "the chemical sector is characterized by high health and safety risks, by the potentially strong impact of emissions and waste on the environment, and by company mergers and reorganizations".[50]

Some physical research on the nature of the universe, like the one carried out by CERN, can affect the religious sensitivities of certain groups. While this can hardly be seen as an issue of research ethics, it nevertheless appears that some scientists feel that the discussion of these themes forms a part of their societal responsibility. Thus, in October 2012, CERN organised a

[42] Kovac, Jeffrey, "Gifts and Commodities in Chemistry", *HYLE: International Journal for Philosophy of Chemistry*, 2001, 7 (2), p. 142.
[43] University of Oxford. *Welcome to Chemistry: Department of Chemistry Graduate Handbook 2013/14*, *op. cit.*, p. 27; Doss & Popkin, op. cit., pp. 4-8.
[44] Hartmut, et al, op. cit., 2011, 50 (37), p. 8484.
[45] Schummer, op. cit., 2001, p. 108.
[46] *Ibid*., p. 111.
[47] Claus Jacob and Adam Walters, "Risk and Responsibility in Chemical Research: The Case of Agent Orange", *HYLE: International Journal for Philosophy of Chemistry*, 2005, 11 (2), p. 149.
[48] Schummer, op. cit., 2001, p. 114.
[49] Davis, op. cit., 2002, p. 31.
[50] Hartmut, et al, op. cit., 2011, p. 8487.

special debate between scientists and theologians concerning the conflicts between scientific and religious conceptions of the universe.[51]

Research including *human participants or animal testing* is usually a part of interdisciplinary research involving biology and medicine – all issues of this type are covered by other reports. Historically, the most famous cases of unethical human subjects experiments, specific to chemistry and physics, have been the ones linked to radiation and chemical weapons development. Toxicology is another discipline in which experiments on live subjects are more frequent. There is a risk of poisoning, explosions and pollution when dealing with chemical substances - professional codes of conduct usually prescribe responsibility for health, safety and environmental impacts. Privacy issues may also arise in the publication of results.[52] For example, the American Physical Society's Guidelines on Professional Conduct state:

> The results of research should be recorded and maintained in a form that allows analysis and review. Research data should be immediately available to scientific collaborators. Following publication, the data should be retained for a reasonable period in order to be available promptly and completely to responsible scientists. Exceptions may be appropriate in certain circumstances in order to preserve privacy, to assure patent protection, or for similar reasons.[53]

4 Institutionalisation: EU and International

The institutionalisation of research ethics in the disciplines of natural science covered by this report takes the form of publication guidelines and professional codes of conduct, formulated by major national or international professional or scientific societies. Special work groups or task forces are established to promote ethical values and principles.

Ethical discussions in natural sciences are often taken up by major national and international societies. In chemistry, the European Association for Chemical and Molecular Sciences (EuCheMS) has established a Working party on Ethics in Chemistry. The working party includes "a network of representatives of EuCheMS member societies" which works "to promote the understanding of the involvement and importance of ethical considerations in all areas of the education and practice of chemical research and applied chemistry".[54] The working party has organised a couple of symposia on ethics in chemistry and published the "Ethical Guidelines for Publication in Journals and Reviews".[55] Similar undertakings were made by the American Chemical Society (ACS), which established a Committee on Ethics with the mission to promote and support "high standards of ethical conduct and integrity in the community of chemistry and related disciplines for the benefit of science and society".[56] As is the case with most of these kinds of societies, the Committee serves "as an educational

[51] *Cf*. Gill, Victoria, "Big Bang: Is there room for God?", *BBC Science and Environment News*, 19 October 2012. http://www.bbc.com/news/science-environment-19997789.
[52] Doss and Popkin, op. cit., p. 21.
[53] http://www.aps.org/policy/statements/02_2.cfm
[54] http://www.euchems.eu/divisions/ethics-in-chemistry.html.
[55] EuCheMS: the European Association for Chemical and Molecular Sciences, *Ethical Guidelines for Publication in Journals and Reviews*, 2006.
http://www.euchems.eu/fileadmin/user_upload/binaries/Ethicalguidelines_tcm23-54057.pdf
[56] http://www.acs.org/content/acs/en/about/governance/committees/ethics.html.

resource and clearinghouse, but not as an adjudication body".[57] According to its goals, the ACS includes three subcommittees: Communication and Awareness, Education and Materials and Programming and screening.[58] The ACS has published its own "Ethical Guidelines to Publication of Chemical Research"[59], in addition to "The Chemical Professional's Code of Conduct".[60] In chemical industry, the International Council of Chemical Associations (ICCA) coordinates Responsible Care, a "global initiative that drives continuous improvement in health, safety and environmental performance, together with open and transparent communication with stakeholders".[61] The UK's Royal Society of Chemistry, "world's leading chemistry community"[62] also aims to "uphold and advance the standards of (…) conduct" as well as serving "the public interest",[63] with its publishing and educational activity. Scientific societies and associations also share a strong commitment to scientific excellence. On the European level, ChemPubSoc Europe represents 16 European chemical societies in their "commitment to scientific excellence, to publishing ethics, and to the highest standards in publication"[64]. ChemPubSoc Europe and its Asian sister organization, the Asian Chemical Editorial Society (ACES), mutually support each other in the publication of their journals Chemistry-A European Journal, Chemistry-An Asian Journal, and ChemSusChem[65]. Internationally, the International Union of Pure and Applied Chemistry (IUPAC) aims to advance the global aspects of the chemical sciences and to contribute to the application of chemistry in the service of mankind. [66] In so doing, IUPAC promotes norms, values, standards and ethics of science[67] and advocates the free exchange of scientific information and unimpeded access of scientists to participation in activities related to the chemical sciences. IUPAC publishes a number of journals: Chemistry International[68], Pure and Applied Chemistry[69] and Macromolecular Symposia[70]. IUPAC contributes to a wide range of chemistry related issues, such as biosafety and biosecurity, raising awareness regarding multiple uses of chemicals and chemical weapons, and discussions on the role of science

[57] http://www.acs.org/content/acs/en/about/governance/committees/ethics/about.html.
[58] *Ibid*.
[59] American Chemical Society, *Ethical Guidelines to Publication of Chemical Research*, 2014. http://pubs.acs.org/userimages/ContentEditor/1218054468605/ethics.pdf
[60] American Chemical Society, *The Chemical Professional's Code of Conduct*, http://www.acs.org/content/acs/en/careers/career-services/ethics/the-chemical-professionals-code-of-conduct.html
[61] http://www.icca-chem.org/en/home/responsible-care/
[62] http://www.rsc.org/aboutus/
[63] http://www.rsc.org/AboutUs/Strategy/index.asp
[64] http://www.chemistryviews.org/details/society/134d1eb2456/ChemPubSoc_Europe.html
[65] http://www.chemistryviews.org/details/society/134d1eb2456/ChemPubSoc_Europe.html
[66] http://www.iupac.org/home/about.html
[67] Draft Elements for Codes of Conduct, 26 February 2011. IUPAC Project nr. 2007-022-2-020: Recommendations for Codes of Conduct, http://www.iupac.org/nc/home/projects/project-db/project-details.html?tx_wfqbe_pi1%5bproject_nr%5d=2007-022-2-020
[68] The news magazine of IUPAC published bimonthly in partnership with De Gruyter; degruyter.com/ci
[69] The IUPAC's official journal is published monthly and includes recommendations, reports, and lectures from conferences; in partnership with De Gruyter; degruyter.com/pac
[70] Contributions in the field of macromolecular chemistry and physics from selected international meetings, including those sponsored by IUPAC

education in raising ethical awareness[71]. The IUPAC has been engaged in the oversight of science in the context of the Chemical Weapons Convention (CWC) since 2002.

In physics, the American Physical Society established a Task Force on Ethics Education in 2004. Its task is to "advise APS on how it can best encourage physics departments to do a better job of educating their students, postdocs, and faculty about scientific ethics; to investigate what materials are available for ethics education; and to develop materials or adapt existing materials to aid physics departments in their efforts".[72] The Task Force prepared reports on ethics education in physics and educational material for use in physics departments. The International Union of Pure and Applied Physics (IUPAP) includes the Working Group on Communication in Physics, which also tackles the challenges of research ethics. The IUPAP published International Guidelines for Ethical Conduct in Scientific Publishing[73].In 2003, the WG organised the workshop Scientific Misconduct and the Role of Physics Journals in its Investigation and Prevention.[74] Each year, IUPAP endorses approximately 30 international conferences, covering very broad to specialized topics relating to physics. IUPAP awards grants to the majority of the conferences, applications for sponsorship can be made via the IUPAP website.

The Sigma Xi Scientific Research Society is the international honor society of science and engineering and one of the oldest and largest scientific organisations in the world, funded in 1886, with more than 200 Nobel Prize winners as members.[75] Sigma Xi issues chapters on topics of ethics and science (such as responsible research, ethical challenges, and ethics training in sciences and education) for colleges and universities, government laboratories, and industry research centers around the world.[76] It publishes influential journal The American Scientist[77] and organizes international conferences, ethics forums, programs and events on the topic.[78] SigmaXi publishes ethics publications in form of booklets (e.g. examining ethical issues and solutions in scientific peer review and authorship), forum proceedings (e.g. discussing new ethical challenges in science, societal implications of science and technology, issuing forum participants' conclusions and recommendations about ethical issues in science) and American Scientist articles (e.g. a series of essays that explore ethical issues in peer review and authorship)[79]. SigmaXi is very active in the area of peer-reviewed research in interdisciplinary and international collaborations, developing "a plan to research interdisciplinary and international variations in peer-review and authorship practices. The findings will form the basis of a workshop curriculum that chapters and classes can use to explore these issues."[80]

[71] http://www.iupac.org/publications/ci/2009/3102/3_pearson.html; http://www.sussex.ac.uk/Units/spru/hsp/pdfbulletin.html
[72] http://www.aps.org/programs/education/ethics/background.cfm.
[73] iupap.iop.org/ga/ga25/appendix-5.pdf
[74] http://iupap.org/working-groups/wg-2-communication-in-physics/; report available here: http://www.isn-oldenburg.de/~hilf/vortraege/london03/report2EPS.pdf.
[75] https://www.sigmaxi.org/about
[76] https://www.sigmaxi.org/programs/ethics-and-research/ethics-publications
[77] https://www.sigmaxi.org/publications
[78] https://www.sigmaxi.org/programs/ethics-and-research/ethics-events-programs
[79] https://www.sigmaxi.org/programs/ethics-and-research/ethics-publications
[80] http://www2.sigmaxi.org/programs/ethics/ethicsprograms.shtml

The European Physical Society (EPS), founded in Geneva in 1968, has more than 120,000 members from 42 National Physical Societies in Europe from all fields of physics and European research institutions[81]. Additionally, EPS Associate Membership is open to European research centers and institutions, universities, industrial partners, publishers, any organisation supporting physics (these include CERN, HZB - Helmholtz Zentrum Berlin and JINR - Joint Institute for Nuclear Research, among others). EPS engages in strengthening ties among physicists in Europe in relation to physics research. In addition, EPS works to advance physics science policy and education, issues publications, organizes conferences and is active in physics training and education. EPS actively:

- advocates physics research and its contribution to the economic, technological, social and cultural advancement in Europe;
- represents the European physics community, providing independent input into science policy issues in Europe;
- supports the role of physicists to actively engage in the design and implementation of European science policies;
- designs and implements programs to develop the European physics community and physics research;
- provides a forum for EPS Members to discuss common issues and share best practice; engages in activities to reduce European fragmentation in physics research, funding and education;
- cooperates with international physical societies to promote physics, to support physicists worldwide and to foster international collaboration.[82]

EPS publishes newsletters and bulletins about activities of EPS, member societies and partners, and articles on a number of topics (e.g., important research in physics, results, ideas, concepts of broad interest to physics community). For example, EPS' The European Journal of Physics publishes articles that aim to assist in maintaining and improving the standard of taught physics in universities and other institutes of higher education[83]. EPS also supports high standards in physics publishing in Europe through EPS recognized journals[84]. Strong international collaboration is made possible through reciprocal member societies. National physical societies from across the world have signed mutual agreements. For example, APS has such agreement with other national societies regarding the exchange of certain membership privileges, such as submitting papers to reciprocal society meetings with the same privileges as members and registering and subscribing to reciprocal society publications at member rates.[85] Similarly, EPS has bilateral agreements with physics societies in Europe and internationally. A selection of national societies cooperate with the EPS, demonstrating strong networking in the physics community and the globalisation of common scientific practices: American Physical Society, Astronomische Gesellschaft, Australian Institute of Physics, Canadian Association of Physicists, Deutsche Bunsen-Gesellschaft für Physikalische Chemie, International Society for Theoretical Chemical Physics, The Chinese Physical Society, The Japan Society of Applied Physics, The Physical Society of Japan, European Materials Research Society, European Association for Chemical and Molecular Sciences and

[81] http://www.eps.org/?page=about_us
[82] http://www.eps.org/?page=about_us_mission
[83] http://www.eps.org/?page=publi_ejp
[84] EPS recognized journal list is available at http://www.eps.org/?page=publi_rec_journals
[85] http://www.aps.org/membership/reciprocal/societies.cfm

Association of Asia Pacific Physical Societies, among many others[86]. It is important to point out that activities of associations and societies typically focus on the integrity, good scientific practice and training within respective fields, and confront ethical issues on an ad hoc basis. Hence, journals, publication series and conference series[87] are seldom dedicated to ethics assessment, but, as is the case of European Journal of Physics, aim towards improving the standard of respective scientific discipline.

4.1 International frameworks and protocols

The most developed ethical frameworks in natural sciences with an international scope are those concerning research publication. These guidelines set out authors' responsibility to present evidence of compliance with laws, regulations and protocols, relevant to the research being published. For a more general framework, guidelines by major scientific institutions such as academies of sciences are sometimes referred to. (For additional information, see sections *2. Ethical Assessment: Approaches and Principles* and *3. Overview of Ethical issues*).

Areas of natural sciences research, especially those that present potential high risk to the society and environment, are represented through international frameworks and protocols, which are further adopted at national level. In chemistry, for example, there are several international conventions, resolutions, treaties and protocols with regard to the use of chemicals that are generally reflected in the codes of conduct, whether on national or international level, and address activities both in science and industry. The aim of these international agreements, prohibitions and requirements, is to regulate scientific and professional activities, also with regard to guaranteeing and promoting general safety and wellbeing. For example, the United Nations Environmental Programme (UNEP), contributes to the development of international environmental conventions, promotes environmental science in conjunction with policy, and coordinates the development and implementation of policy with national governments and regional institutions in conjunction with environmental non-governmental organisations (NGOs). [88] It issues a number of codes of conduct, such as the Climate Technology Network (CTN) Code of Ethics[89] and Code of Ethics on the International Trade in Chemicals[90]. Other notable frameworks and conventions include the Strategic Approach to International Chemicals Management – an international policy framework to foster the sound management of chemicals - [91], the IUPAC Global Framework for Implementing Consistent Ecological Risk Assessment of Pesticides for Sustainable Agriculture[92], the Stockholm Convention on Persistent Organic Pollutants[93], The Rotterdam Convention[94], The Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal[95], The Vienna Convention for the Protection of the

[86] http://www.eps.org/?page=membership_cs
[87] See Annex for the extensive list
[88] http://en.wikipedia.org/wiki/United_Nations_Environment_Programme
[89] http://www.unep.org/climatechange/ctcn/Portals/50212/CTN%20code%20of%20conduct%20310114.docx
[90] http://www.unep.org/publications/search/pub_details_s.asp?ID=2113
[91] http://www.chem.unep.ch/saicm/
[92] Report: http://www.iupac.org/publications/ci/2013/3506/index.html
[93] http://chm.pops.int
[94] Covers chemicals that have been banned or severely restricted for health or environmental reasons, http://www.pic.int/home.php?type=t&id=5&sid =16
[95] http://www.basel.int

Ozone Layer and The Montreal Protocol on Substances that Deplete the Ozone Layer[96], The Chemical Weapons Convention[97], and the UN Security Council Resolution[98], among many others. Beyond regulation, the aim of these frameworks is to foster international collaboration among scientists, to contribute to the development of systematic and harmonized risk assessment, and the transfer of risk assessment methodologies and knowledge to emerging regions of the world. [99] The IUPAC Global Framework for Implementing Consistent Ecological Risk Assessment of Pesticides is a good example of such framework and its Objectives specifically mention interaction with the emerging regions:

- Identify and prioritize key issues related to pesticide ecological risk assessment in scientifically emerging regions.
- Develop an integrated framework and guidance document for the application of ecological risk assessment (ERA) methodologies that can be applied to the pesticide regulatory process.
- Develop training materials and plan for two workshops in order to transfer this approach to selected areas.
- Facilitate workshops in scientifically emerging countries (Brazil and China) to promote the documents developed as described above, based on state-of-the-art-science and past IUPAC projects.[100]

In physics, one sees a major effort in propagating the importance of scientific integrity. Societies, such as Sigma Xi, aim to foster professionalism among its members by "cultivating a keen awareness of ethical issues and a proactive approach to research integrity as it applies to each stage of the research process, such as: Record-keeping, Avoiding conflicts of interest, Sharing authorship, Conducting peer review, Securing tenure and career advancement, Talking with the media. [...] When scientists uphold ethical best practices in these and other areas, they contribute to an accurate scientific record, public trust in science, and efficient use of research funds. ... Sigma Xi is here to help researchers, both young and established, think about these issues and to set a good example for their colleagues"[101]. Similarly, through its committees (Committee on International Scientific Affairs (CISA), Committee on International Freedom of Scientists and Forum on International Physics), APS engages in international affairs with regard to issues that relate to the physics community:

- Science: International R&D collaborations are on the rise; countries are partnering to build big facilities.
- Industry: Companies are increasingly multinational; US companies are moving R&D facilities offshore.
- Education: The US competes for the world's best talent; it needs to attract and retain first-rate students and scientists.

[96] http://ozone.unep.org
[97] http://www.opcw.org
[98] Resolution1540 (2004) "obliges States, *inter alia*, to refrain from supporting by any means non-State actors from developing, acquiring, manufacturing, possessing, transporting, transferring or using nuclear, chemical or biological weapons and their delivery systems". http://www.un.org/sc/1540/
[99] http://www.oecd.org/env/testguidelines
[100] http://www.iupac.org/home/projects/project-db/project-details.html?tx_wfqbe_pi1%5bproject_nr%5d=2010-056-1-600
[101] http://www2.sigmaxi.org/programs/ethics/index.shtml

- Policy: National S&T policies are affected by global events; federal R&D funding Influences US participation in international large-scale collaborations.[102]

APS collaborates with the International Union of Pure and Applied Physics (IUPAP) Working Group on Women in Physics in offering IUPAP Grants for Women in Developing Countries, to help women from developing countries attend regional or international conferences, workshops, or schools.[103] Furthermore, there is direct collaboration between U.S. and China, with APS and the Chinese Physical Society (CPS) organizing the U.S.-China Young Physicist Forum on Condensed Matter Physics and Materials Physics. As mentioned in the previous section, EPS also has established cooperation on national level and worldwide.

5 Institutionalisation: National

In the EU, e.g. in Netherlands, Germany and Austria[104], legislation and practices of ethics assessment in science are, for the most part, decentralized and independent of government. Various national ethics committees evaluate scientific research, especially in intrusive areas of scientific research, e.g. involving human subjects, animal experimentation, or environmental issues, among others. In most cases, the committees have regulatory authority and issue legally required permissions for conducting such research. Furthermore, a number of public-private partnerships exist relating to ethics assessment and civil society organisations are represented in various stakeholder dialogues organized on important ethical issues. In most EU countries, a number of government (-associated) bodies engage in activities related to ethics assessment, such as environmental impact assessment, social impact assessment, and technology assessment. In The Netherlands, for example, the two main national ethics committees preside over areas of scientific research related to animal experimentation and human subject research, whereas environmental issues are covered by the agencies[105]:

- The Central Committee on Animal Experimentation (Centrale Commissie Dierproeven; CCD) is an independent, government-funded body whose legal tasks include reviewing research involving animal experimentation, providing permits for such research on a case by case basis, providing official recognition for animal experimentation ethics committees (Dierexperimentencommissies; DECs), and creating guidelines for animal experimentation ethics assessment procedures by DECs.[106]

- The Central Committee on Research Involving Human Subjects (Centrale Commissie Mensgebonden Onderzoek; CCMO) is an independent, government-funded body that is responsible for implementing the Dutch Medical Research Involving Human Subjects Act (Wet Medisch-Wetenschappelijk Onderzoek met Mensen; WMO). The CCMO's legal tasks include overseeing the operations of the accredited medical ethical reviewing committees (MERCs), creating guidelines on assessment procedures

[102] http://www.aps.org/programs/international/index.cfm
[103] http://www.aps.org/programs/women/scholarships/iupaptravel.cfm
[104] This section on national legislation is based on the SATORI Country reports for Netherlands, Germany and Austria
[105] SATORI Country report: Netherlands
[106] http://www.zbo-ccd.nl/over-de-ccd

by MERCs and the selection of members of MERCs, and reviewing the ethics of research in special cases—that is, in particular fields or when an appeal is filed against a decision by a MERC.[107]

- The *Netherlands Commission for Environmental Assessment* (Commissie voor de Milieueffectrapportage) is an independent, government-funded body that provides advisory and capacity development services with regard to environmental assessment.[108]

- PBL Netherlands Environmental Assessment Agency (part of the Ministry of Infrastructure and the Environment)

- National Institute for Public Health and the environment (RIVM; part of the Ministry of Health, Welfare and Sports)

In Germany[109], the main legal provision for research and innovation in Germany is the German Basic Law.[110] The major legal provisions for legislation on impact assessment are laid down in the Environmental Impact Assessment Act[111], which is mainly a translation of European Directives on the regulation of environmental impact[112]. The Act applies to a wide range of public and private projects and also concerns research in natural sciences, in areas that have impact on the environment[113]. The German Ethics Council's (Deutscher Ethikrat) aim is to "pursue the questions of ethics, society, science, medicine and law and the probable consequences for individual and society that result in connection with research and development, in particular in the field of the life sciences and their application to humanity".[114] Among its most important duties are: "informing the public and encouraging discussion in society, engaging the various social groups" and "preparing opinions and recommendations for political and legislative action".[115] Additionally, The Council of Science and Humanities (Wissenschaftsrat) advises the government on the development of science and higher education systems.[116] Several agencies and commissions preside over environment and sustainability issues. Unlike in most European countries, Germany has provisions in regard to research integrity laid down in criminal law (in the German criminal code[117]) and in the

[107] http://www.ccmo.nl/en/tasks-of-the-ccmo
[108] http://www.eia.nl/en
[109] Refer to SATORI D1.1 Country report: Germany, June 2015.
[110] Basic Law for the Federal Republic of Germany (Grundgesetz für die Bundesrepublik Deutschland), 23.05.1949.
English: http://www.gesetze-im-internet.de/englisch_gg/basic_law_for_the_federal_republic_of_germany.pdf
German: http://www.gesetze-im-internet.de/bundesrecht/gg/gesamt.pdf
[111] Environmental Impact Assessment Act (Gesetz über die Umweltverträglichkeitsprüfung), 12.02.1990.
http://www.gesetze-im-internet.de/bundesrecht/uvpg/gesamt.pdf
[112] http://ec.europa.eu/environment/eia/eia-legalcontext.htm
[113] http://faolex.fao.org/docs/pdf/ger36861E.pdf
[114] http://www.ethikrat.org/about-us/our-mandate
[115] Ibid.
[116] http://www.wissenschaftsrat.de/en/about/function.html.
[117] German Criminal Code (Strafgesetzbuch), 15.05.1871.
English: http://www.gesetze-im-internet.de/englisch_stgb/index.html
German: http://www.gesetze-im-internet.de/bundesrecht/stgb/gesamt.pdf

German Act on Copyright and Related Rights.[118] Furthermore, soft law regulations in the form of codes of conduct for scientific research are based on recommendations issued by the German Research Foundation (Deutsche Forschungsgemeinschaft; DFG). These recommendations lay down principles for scientific practice (e.g. proper documentation, a critical attitude towards one's own findings) as well as recommended organisational structures. DFG policy recommendations have been adopted by universities and professional organisations across Germany. Moreover, some policies are field-specific. The specific issue of dual-use is regulated by the German Ethics Council, in a collaborative draft issued by the DFG and the German National Academy of Sciences: "Scientific freedom and scientific responsibility; Recommendations for handing security-relevant research"[119]. A substantial part of ethics assessment is organized at the regional and state levels and at the level of research institutes.

In Austria, on the level of national law, most provisions with regard to ethics assessment in scientific research are fairly abstract, formulated as general values, such as the *freedom of research*.[120] Ethics assessment at governmental level mainly relates to policy guidance performed by advisory councils. In science and research, mandatory ethics assessment is provided by Research Ethics Committees for respective scientific fields and/or topics, and by the National Agency for Animal Research. Other areas of interest, such as dual use, data protection, environmental impact assessment, or genetically modified organisms (GMOs), are further regulated by specific provisions. The Austrian Research Promotion Agency, the Austrian Science Fund and individual ministries provide research funding. Austria has three policy oriented national ethics bodies: The Austrian Bioethics Commission, the Advisory Board on biotechnology and genetic engineering, and the National Committee for the protection of animals used for scientific purposes (*Tierversuchskommission*). Similar to Germany, the Austrian National Committee for the protection of animals used for research purposes was established by the Act on the Protection of Animals Used for Scientific Purposes[121], which is the transposition of the respective European Union Directive. The Environment Agency Austria (*Umweltbundesamt*) has a central role in environmental impact assessment and provides advisory services across a wide range of areas, mainly in the fields of climate change mitigation and adaptation, energy efficiency and renewable energy, air quality, water quality and resources, biodiversity, GMOs, nature protection, waste and resource management, chemicals, environmental legal advice as well as data management, including monitoring and reporting.[122] Research on human subjects and animal research are regulated by Ethics Committees and consultation with a Committee before conducting research is

[118] Act on Copyright and Related Rights (Gesetz über Urheberrecht und verwandte Schutzrechte), 09.09.1965. http://www.gesetze-im-internet.de/bundesrecht/urhg/gesamt.pdf
[119] German Research Foundation (Deutsche Forschungsgemeinschaft), Academy of Sciences Leopoldina (Nationale Akademie der Wissenscahften Leopoldina), Scientific Freedom and Scientific Responsibility. Recommendations for Handling Security-Relevant Research, 2014. http://www.leopoldina.org/uploads/tx_leopublication/2014_06_DFG-Leopoldina_Scientific_Freedom_Responsibility_EN.pdf
[120] Freedom of research is guaranteed by Article 17 of the Basic Law on the General Rights of Nationals (*Staatsgrundgesetz*). http://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=10000006
[121] http://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20008142
[122] http://www.umweltbundesamt.at/en/services/environmental_consulting/#

obligatory. Important international provisions adopted by Austria and transposed into national legislation are:[123]

- Regulation on clinical trials on medicinal products for human use (2014/536/EU),
- Council Directive concerning medical devices (93/42/EEC),[124]
- Directive on the protection of animals used for scientific purposes (2010/63/EU).

Furthermore, most Austrian universities have established independent non-statutory Ethics Committees, which provide reviews on individual research projects or advise the university on issues concerning ethics.

France has a longstanding tradition of scientific research in which the State plays a significant role. Obligatory ethics review is limited to "interventional research" and to the collection of human biological samples for scientific purposes and impact assessment related to the environment is the subject of the Environment Code.[125] The two main government ministries that share responsibility for research and innovation policy in France are the Ministry of Education, Higher Education and Research[126] and the Ministry for the Economy, Industry and Digital Affairs.[127] The French public research and innovation system is structured around a small number of agencies that fund the research projects carried out mostly by public research institutions. The French national Research Agency (ANR) is responsible for implementing the funding of research. ANR encourages the respect of its own framework (established in 2014) with regards to ethics policy and scientific integrity. Additionally, ANR's Code of ethics from 2009 enforces the principles of objectivity, selflessness, respect of information confidentiality during the evaluation process, as well as prevention of conflict of interest by making it obligatory for all concerned parties.

The Ethics in Science Commission (ESC) of the Polish Academy of Sciences's (PAS)[128], established in 2010, issues opinions on breaches of ethical principles by universities, scientific units of the Academy and research institutions. The Commission conducts in-house ethics assessment and guidance on scientific integrity and can, on its own initiative, refer matters to competent disciplinary committees. ESC issues The Ethical Code of a Researcher and disseminates standards of scientific integrity. The Commission comprises 9 members representing scientific and higher education community. The Executive Act of the Minister of Science and Higher Education (2010) on the procedure of selecting members of the Commission on Ethics in Science[129] lays down rules on the manner in which the

[123] SATORI D1.1 Country report: Austria.
[124] The Directive is subject to reform.
[125] Legifrance. http://www.legifrance.gouv.fr/affichCode.do?cidTexte=LEGITEXT000006074220
[126] Official web site of MENESR. http://www.enseignementsup-recherche.gouv.fr/.
[127] Official web site of the French Ministry for the Economy, Industry and Digital Affairs, http://www.economie.gouv.fr/les-ministeres/missions-ministere-economie-redressement-productif-numerique.
[128] http://www.english.pan.pl
[129] http://www.instytucja.pan.pl/images/2013/Komisja_Etyki/rozporz%C4%85dzenie_Ministra_Nauki_i_Szkolnictwa.pdf

Commission's binding opinions shall be used, as well as on how it is funded from the government budget.

The Spanish National Evaluation and Foresight Agency (ANEP) is part of the Directorate General for Research and Management of the National R&D + Innovation Plan, within the State Department of Research of the Ministry of Science and Innovation. ANEP performs scientific evaluation. Moreover, there are a number of Spanish national associations that conduct ethics assessment of research, mainly in bioethics and biomedical research. They include the *National Association of Research Ethics Committees*, the *Network of Ethics Committees in Universities and Public Research Centres in Spain*, and the *Spanish Association of Bioethics and Medical Ethics*. These organisations generally contribute to ethics assessment practices through reflection and discussion on important contemporary ethics topics among members of the profession and society at large. The Associations aim to promote basic and further training of those who are or will form part of the RECs.

The research community in Serbia is primarily represented by two national organisations: the *Serbian Academy of Science and Arts* (SANU)[130] and the *Association of Institutes of Serbia*. SANU's structure, responsibilities and governing are defined by separate Law[131]. The highest administrative body of the SANU is the Assembly, which is made up of all of the members, while the Presidency represents the executive body. SANU is comprised of eight departments and eight institutes. The *National Committee for Bioethics of the Republic of Serbia* was founded as a result of cooperation between SANU, Commission for Cooperation, UNESCO and the Ministry of Foreign Affairs of Serbia in 2003. Later, two other National Ethics Committees (the Ethics Board of Serbia and the Ethics Council for Welfare of Animals used in Animal Testing both formally established by Law) were established.

While there is no single, coordinated approach to ethics assessment in UK, it has a very well developed system of ethics assessment with a wide variety of organisations engaging in ethics assessment or ethics guidance. National associations for R&D professions play part in upholding and promoting ethical standards in the UK. The Royal Society of Chemistry (RSC) is the UK's professional body for chemical scientists.[132] The RSC has provisions for 'Ethical Guidelines and Conflict of Interest' for RSC publications. Where guidelines are breached or appear to be so, the RSC consults its Code of Conduct and Best Practice Guidelines of the Committee On Publication Ethics (COPE) and acts accordingly.[133] As part of its ethical policy, the RSC is a member of CrossCheck (a multi-publisher initiative to screen published and submitted content for originality).[134] It also has a publications related policy on Experiments Involving Live Subjects.[135]

[130] https://www.sanu.ac.rs/English/Index.aspx
[131] Law on Serbian Academy of Science and Arts, Official Gazette of the Republic of Serbia, No. 18/10.
[132] RSC, "About us". http://www.rsc.org/about-us/
[133] RSC, "Ethical Guidelines for Publication in Journals and Reviews". http://www.rsc.org/Publishing/Journals/guidelines/EthicalGuidelines/EthicalGuidelinesandConflictofInterest/sect1.asp
[134] RSC, "CrossCheck". http://www.rsc.org/Publishing/Journals/guidelines/EthicalGuidelines/CrossCheck/CrossCheck.asp
[135] Ibid.

The federal government only has limited authority over the institutions for higher education and research in the U.S., mostly focusing on the promotion of educational policies, administration of federal assistance programs, and enforcing educational related civil rights law. The U.S. National Academies (NA) consists of the National Academy of Science, the National Academy of Engineering, the Institute of Medicine and the National Research Council, which serve collectively as the scientific national academy of the U.S. With regards to ethics assessment, the primary role of NA seems to be agenda and standard setting.

The National Research Council is a council under NA and can be considered its working arm. The mission of the council "[…] is to improve government decision making and public policy, increase public understanding, and promote the acquisition and dissemination of knowledge in matters involving science, engineering, technology, and health".[136] Advice from NRC has led to e.g. legislative acts improving the competitiveness of the US[137] and changes to the U.S. drug safety regulation. Another example of NRC's work is on climate change, a contested issue in the U.S. scientific debate. Here the council stated that the work of the Intergovernmental Panel on Climate Change represented the view of the established scientific community well.[138] The individual national academies may further have governmental advisory boards, e.g. U.S. National Academy of Sciences' Board on Science, Technology, and Economic Policy.[139]

In China, government plays a strong role in the public research and innovation system, thus the independence and freedom of important research institutions is very limited. The Ministry of Science and Technology[140] (MOST) makes S&T development plans and policies, organizes demonstration, assessment, acceptance and policy making of major S&T projects and provides advice. MOST also oversees the establishment and restructuring of research institutes and is responsible for budgeting and supervision of funds related to S&T projects.[141]

The Chinese Academy of Sciences[142] (CAS) is a natural science and high-tech research and development center. The Science Ethics Committee[143] of the CAS, established in 1996, is responsible for supervising the ethics of researchers and scientists.[144] It hosts annual seminars dealing with various topics of ethics in science and technology.[145]

[136] Nationalacademies.org. National Research Council. http://www.nationalacahttp://sites.nationalacademies.org/pga/step/index.htmdemies.org/nrc/
[137] Nationalacademies.org. Our Advice in Action. http://www.nationalacademies.org/about/advice/index.html
[138] Cicerone, Ralph J. et al, *Climate Change Science: An Analysis of Some Key Questions*, The National Academic Press, Washington. 2001. http://www.nap.edu/openbook.php?record_id=10139
[139] Sites.nationalacademies.org, Board on Science, Technology, and Economic Policy (STEP). http://sites.nationalacademies.org/pga/step/index.htm
[140] 科学技术部
[141] http://www.most.gov.cn/eng/organization/Mission/index.htm
[142]中国科学院
[143]学部科学道德建设委员会
[144] http://www.casad.cas.cn/channel.action?chnlid=221
[145]科技伦理研讨会

The China Association for Science and Technology[146] (CAST) is the largest national non-governmental organisation of scientific and technological workers in China, consisting of 201 member societies and nationwide local branches. CAST has a Special Committee on the Ethics and Rights of Science and Technology Workers[147], which conducts supervision of the R&D integrity of Chinese S&T scholars and aims to improve scientific ethics through regulations.[148]

As natural sciences deal with common pressing issues across the globe (e.g., issues related to environment, energy, food, health, safety, education), they require international collaboration and exchange of knowledge, as well as adoption of mutually agreed international frameworks, policies and regulations. The common agenda of representative organisations centers on the promotion and development of the field and scientific research, exchange and dissemination of knowledge and its applications in order to improve the welfare of the society, and collaboration on national and international level, with related disciplines, and also by bridging science and industry. In effect, European national societies and associations have adopted ethical codes through umbrella European and international organisations.

In chemistry, two such examples are the ICCA's Global Charter[149] on international and EuCheMS[150] on the European level. The EuCheMS Code of Conduct requires all its members to:

- have special regard at all times to the public interest [and to]
- the maintenance of the highest standards of competence and integrity
- conduct themselves honourably in the practice of their profession
- observe the provisions of the rules and regulations of [name of society]
- promote the interests of the [name of society] and maintain the dignity and welfare of the [name of society]. [151]

At national level, the principles of individual societies with regard to ethics and good conduct are similar to those of EuCheMS code of conduct. For example, the German Chemical Society (GDCh - Gesellschaft Deutscher Chemiker), the largest learned society and professional association of chemists in Europe[152], issues code of conduct[153] and "brings together people working in chemistry and the molecular sciences and supports their striving for positive, sustainable scientific advance – for the good of humankind and the environment, and a future worth living for". [154] Some national associations have adopted their structure by modeling established learned societies and professional organisations. For example, the Chemical Society of Japan (CSJ) was modeled after the British Chemical Society[155], and shares similar

[146]中国科学技术协会

[147]科技工作者道德与权益专门委员会

[148] http://zt.cast.org.cn/n435777/n435799/n13518146/n13518511/13522275.html
[149] http://www.icca-chem.org/Public/Responsible%20Care/RCGC-online%20guidance.pdf
[150] For a complete list of 41 European societies, see http://www.euchems.eu/members/member-societies/a-g.html
[151] The EuCheMS Code of Conduct was approved by the General Assembly in 1985. http://www.euchems.eu/members/code-of-conduct.html
[152] GDCh was founded in 1867 and today has 31,000 members from academia and industry
[153] https://www.gdch.de/gdch/ueber-uns/satzung-und-verhaltenskodex.html
[154] http://en.gdch.de/main-navi/gdch/about-us.html
[155] The precursor of the Royal Society of Chemistry, http://en.wikipedia.org/wiki/Chemical_Society_of_Japan

activities with regard to the promotion of chemistry in science and industry, organisation of academic conferences, publishing of journals and books, etc.[156] The CSJ Environmental Charter '99 issues following policies and activities concerning environment and chemistry:

> 1. The Chemical Society of Japan will actively address environmental and safety issues associated with chemical substances as fundamental issues underlying all of its activities.
> 2. Every member of the Society will ensure that his/her academic activities in his/her area of expertise will be fully utilized for the best practicable resolution of environmental and safety issues for chemical substances.
> 3. For these purposes, a new structure will be established in the Society that will be charged with such tasks as:
> - Fostering research on environmental and safety problems
> - Increasing cooperation with academic societies in related disciplines
> - Developing human resources
> - Making recommendations to industries, governments, and the public
> - Strengthening international cooperation.[157]

The Società Chimica Italiana[158] Charter of Ethical Principles for the Chemical Sciences is a representative example of general ethical principles, typically adopted by national (and international) chemistry societies and associations. It emphasizes "opposition to the improper use of chemistry, safeguarding of the environment and its ecosystems, improving the quality of life without harming the world around us, dissemination of awareness of the advantages and benefits of the chemical sciences in public opinion." [159] The Charter states the application of ethical principles in three different areas:

- Experimental research activities—with particular regard to the synthesis of new products,
- The activities of workers in various industrial and manufacturing sectors,
- The activities of Corporations carried out through their Managers. [160]

Furthermore, it defines propositions that are "specifically practicable in the contexts of experimental and manufacturing activities"[161], emphasizes the importance of awareness of the chemical sciences and professional education, the cultural commitment of experts of chemistry and chemical technology, issues of 'dual use' in chemistry and areas of greatest risk for improper use of chemistry. The Charter's ethical principles refer to and acknowledge *conceptual dualism*:

> Each individual's general ethical principles belong to his or her upbringing and to the traditions of the country in which he or she lives. Culture, Morality, Ideology, and Religion exert considerable influence over individual behavior, and differences among nations are significant. A General Charter of Ethical Principles for the Chemical Sciences must take such differences into account and put forward Principles that can be universally shared.[162]

[156] http://www.chemistry.or.jp/en/
[157] http://www.csj.jp/csj-en/activities/eco/env-c.html
[158] https://www.soc.chim.it/en
[159] http://oldsoc.chim.it/it/documenti/carta_dei_principi
[160] Ibid., p. 4
[161] Ibid., p. 2
[162] Ibid., p. 2

The German Physical Society (DPG - Deutsche Physikalische Gesellschaft) represents 62,727 members (above 50% are students and PhDs) from the fields of pure and applied physics in an effort to foster the exchange of ideas between its members (from young scientists to Nobel Prize laureates) and foreign colleagues. DPG also encourages scientific dialogue and the exchange of ideas through annual meetings (attended by more than 10,000 experts), organizes German Conference of Women in Physics, issues internationally renowned awards (the Max-Planck-Medal for Theoretical Physics, the Stern-Gerlach-Medal for Experimental Physics and the Gustav-Hertz-Prize for Young Physicists), supports competitions such as the "International Young Physicists' Tournament", promotes innovative school projects, and organizes and promotes advanced training courses for teachers[163]. DPG active cooperates with national and international associations and has an advisory role in matters of research promotion, education and career. The Society engages in latest sociopolitical issues and is responsible for the publication of two physics journals. The DFG Code of Conduct for Members covers areas of social responsibility, scientific misconduct, reproducibility, scientific publishing, reviewing and refereeing and solving conflicts of interest, as well as stating procedures for dealing with scientific misconduct. The DPG "binds itself and its members to advocate for freedom, tolerance, veracity and dignity in science and to be aware about the fact, that the people working in science are responsible to a particularly high extent for the configuration of the overall human activity"[164]. General aims, especially those of promotion and dissemination of physical sciences, international collaboration, and proper scientific conduct, are expressed by all national societies under review[165]. Most national associations and societies adopt codes of conduct from international organisations they are members of. For example, the Swedish Physical Society (Svenska Fysikersamfundet) unites Swedish physicists, physics teachers and other practitioners, supporters and friends of the physical sciences, with the aim "to promote physics research and applications, to spread knowledge about physics and physics education, and to stimulate the public interest in physics and the natural sciences in general."[166] The Austrian Physical Society (OePG)[167] has a similar mission, but neither the Swedish or Austrian physical societies issue their own codes of ethics[168].

In the U.S., the National Science Foundation Ethics Education Requirements demand that U.S. institutions provide training in the responsible and ethical conduct of research to undergraduates, graduate students, and postdoctoral researchers participating in funded research projects[169]. These are general requirements for all areas of natural sciences, whereas national societies, such as APS and ACS, help provide physics or chemistry relevant ethics training.

[163] http://www.dpg-physik.de/index.html?lang=en&
[164] http://www.dpg-physik.de/dpg/statuten/kodex_english.html
[165] Reviewed were major and established European and international societies from respective scientific fields.
[166] http://www.fysikersamfundet.se/english.html
[167] https://www.oepg.at
[168] There is no information on CoEs on their websites
[169] http://www.nsf.gov/bfa/dias/policy/rcr.jsp

6 Evaluation

All fields in the natural sciences share common ethical principles and issues. The analysis shows strong international collaboration on major scientific issues, common efforts for the advancement of the respective fields and the promotion of science to general public. A comparison of the aims of international and national organisations did not identify major differences, and ethical codes on national level reflect those of established international associations. To summarise:

- The most often discussed values in the branches of natural science studies in this report are integrity and honesty in terms of data presentation and referencing the work of others and societal responsibility and sustainability, especially regarding the potential risks linked to applications of new knowledge.
- Frequently debated ethical issues include data fabrication and falsification of scientific findings in their effects on the research community and society.
- The most referenced ethical frameworks in these fields are ethical guidelines for research publication and professional codes of conduct.
- Ethical standards in these disciplines are mostly set by major professional and scientific associations, which are also concerned with raising awareness and providing research ethics educational material.

The activities mentioned above are positive, and there is a relatively good degree of consensus regarding the responsible conduct of research both in chemistry and physics (particularly concerning laboratory research). But there are also shortcomings with regard to proper training in ethics, especially in chemistry. University programmes seldom offer proper training and education on ethical issues and responsibilities concerning their field; this is mostly done in informal manner by their supervisors. Ethics assessment is primarily institutionalised in the ethics requirements for federal grants and for human subjects research, thus at the level of national ethics committees. On university level, Ethics Committees (and in U.S., the Institutional Review Board) review all projects dealing with human subjects. Codes of Ethics are developed by individual scientific societies (e.g. American Chemical Society) are not legislated. The American Chemical Society has a Committee on Professional Training that sets standards, but these are seldom introduced in classes, and not systematically. There is some legislation for clinical chemists that deal with medical issues, and those dealing with human subjects typically have COEs based on their professional licenses. The biggest problem regarding ethics assessment in chemistry, at least in U.S., is that nothing is institutionalised (and there are no formal nation-wide standards on ethics training on different degree levels). There is no given procedure or systematic way of thinking about ethical issues with a lot of work taking place on an informal basis. The first step in addressing these gaps is to set some standards, or at least guidelines, for a minimal ethics training and education in universities, so that it becomes a required part of chemistry education. This should take place on different levels: the undergraduate level, bachelor level, and particularly on the doctoral level, when a person is being trained to become an independent researcher. Kovac's book "*The Ethical*

Chemist: Professionalism and Ethics in Science"[170] is an effort in that direction, introducing specific cases and ethical problems faced by both students and practicing chemists, and offering a framework for understanding ethics issues in chemistry.

In general, ethics assessment is a matter of culture of individual disciplines within science. ACS's *The Chemist's Code of Conduct of the American Chemical Society*[171] and the *Code of Ethics of the American Institute of Chemical Engineers*[172] presumably apply to all chemists, and list the responsibilities of chemists to various groups beginning with the responsibilities of chemists to the public. The code is similar to *The Accreditation Board of Engineering and Technology* (ABET)[173] Code of Ethics. Nevertheless, the ACS code lists various responsibilities with no guidance as to how deal with conflicts. If the chemist's responsibility for welfare comes in conflict with the chemist's responsibility to an employer, the code does not say which should have priority. For the engineer, the priorities are clear: Take care of the public first; everything else comes second.[174]

The engineering approach is particularly appealing to the chemist, as engineers deal with practical things, and the concern for public safety and the ideal of the wellbeing of society, is very important. The general approach of the bioethics community to the analysis of cases, and, in the context of ethics education, in setting out hypothetical situations or cases for consideration and approaches to ethical decision-making, is also particularly relevant for chemistry.

There are other areas that need considerate attention, as existing regulations do not reflect the real world situation. The IUPAC Global Framework for Implementing Consistent Ecological Risk Assessment of Pesticides for Sustainable Agriculture project states:

Exponential growth in agricultural outputs during the last decade has boosted pesticide use significantly in many scientifically emerging regions of the world. As the intensity of agricultural production in these countries has increased, pesticide application has also increased, and potential ecological impact has become a growing concern. However, systematic and harmonized environmental risk assessment (ERA) methodologies are either largely lacking and/or do not reflect the real life conditions in these regions/countries.

There is a strong interest from scientists and regulators in these regions to utilize existing datasets and models to begin the process of ERAs to examine the potential risks to natural resources in sensitive areas. This problem is an area where international cooperation among scientists can be extremely effective in transferring knowledge and skills.

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[170] Kovac, J., *The Ethical Chemist: Professionalism and Ethics in Science*, Prentice Hall, Upper Saddle River, 2004.
[171] American Chemical Society, 2012, The Chemical Professional's Code of Conduct http://www.acs.org/content/acs/en/careers/profdev/ethics/the-chemical-professionals-code-of-conduct.html
[172] AIChe, 2006, Code of Ethics, http://sts.aiche.org/content/code-ethics, accessed August 1, 2013. American Institute of Chemists, 1983, Code of Ethics.
[173] http://www.abet.org
[174] Kovac, J., *Ethics in Science: The Unique Consequences of Chemistry, Accountability in Research,* [forthcoming, 2015].

Although significant advances in ERA science and technology have been made over the last decade, there is a dearth of concise and effective guidance documents and training materials for consistent and systematic practices of pesticide environmental risk assessment in scientifically emerging countries. While the agricultural practices and environmental conditions in each country will vary, key concepts and approaches will remain the same.[175]

There is a growing need to prioritize key issues, especially in the emerging regions, and develop an integrated risk assessment framework and guidance, as well as training.

To conclude, consider the following illustrative example, showing differences between codes of ethics as perceived by Europeans and North Americans (Table 1). DIYbio.org is the international community of DIY biologists with with the aim of promoting biotechnology. In 2011 DIYbio.org organized a series of congresses where members from regional groups of amateur biologists from North America and Europe collaborated on the development of a DIYbio code that could later serve as a framework for the community. The draft codes of both groups (Table 1) share many common principles, such as transparency, open access, safety, education, and peacuful purposes. But they also show major differences. Whereas the American draft is proactive (e.g. 'tinkering'), the European draft is much more moderate, alomst restrictive, emphasizing aspects such *modesty, community, respect, responsibility, accountability* (see explanations for each in Table 1).

Europe	*North America*
Transparency Emphasize transparency and the sharing of ideas, knowledge, data and results. *Safety* Adopt safe practices. *Open Access* Promote citizen science and decentralized access to biotechnology. *Education* Help educate the public about biotechnology, its benefits and implications. *Modesty* Know you don't know everything. *Community* Carefully listen to any concerns and questions and respond honestly. *Peaceful Purposes* Biotechnology must only be used for peaceful	OPEN ACCESS Promote citizen science and decentralized access to biotechnology. TRANSPARENCY Emphasize transparency, the sharing of ideas, knowledge and data. EDUCATION Engage the public about biology, biotechnology and their possibilities. SAFETY Adopt safe practices. ENVIRONMENT Respect the environment. PEACEFUL PURPOSES Biotechnology should only be used for peaceful purposes. TINKERING Tinkering with biology leads to insight; insight leads to innovation.

[175] http://www.iupac.org/home/projects/project-db/project-details.html?tx_wfqbe_pi1%5bproject_nr%5d=2010-056-1-600

purposes. *Respect* Respect humans and all living systems. *Responsibility* Recognize the complexity and dynamics of living systems and our responsibility towards them. *Accountability* Remain accountable for your actions and for upholding this code.	

Table 1: The draft codes of ethics from Europe (left) and North America (right)[176]

7 Annex: Key publications, journals and conference series

7.1 Key publications

American Chemical Society, *Ethical Guidelines to Publication of Chemical Research*, 2014. http://pubs.acs.org/userimages/ContentEditor/1218054468605/ethics.pdf

American Chemical Society, *The Chemical Professional's Code of Conduct*. http://www.acs.org/content/acs/en/careers/career-services/ethics/the-chemical-professionals-code-of-conduct.html.

Doss, Heide, and Gabriel Popkin (eds.), *Ethics Case Studies – Teacher Edition*, Case studies developed by the APS Task Force on Ethics Education. http://www.aps.org/programs/education/ethics/upload/Ethics-Case-Studies-Teacher-Edition.pdf

American Physical Society, *Guidelines for Professional Conduct*. http://www.aps.org/policy/statements/02_2.cfm

Davis, M., "Do the Professional Ethics of Chemists and Engineers Differ?", *HYLE: International Journal for Philosophy of Chemistry*, 2002, 8 (1), pp. 21-34.

EuCheMS: the European Association for Chemical and Molecular Sciences, *Ethical Guidelines for Publication in Journals and Reviews*, 2006.

Frank, H., L. Campanella, F. Dondi, J. Mehlich, E. Leitner, G. Rossi, K. N. Ioset and G. Bringmann, "Ethics, Chemistry, and Education for Sustainability", *Angewandte Chemie (International Edition)*, 2011, 50 (37), pp. 8482–8490.

Gardiner, S. M., S. Caney, D. Jamieson and H. Shue (eds.), "Climate Ethics: Essential Readings", Oxford University Press, Oxford, 2010.

[176] http://diybio.org/codes/

Hulme, M., "Why We Disagree About Climate Change: Understanding Controversy, Inaction and Opportunity". Cambridge University Press, Cambridge, 2011, pp. 364.

Jacob, C. and A. Walters, "Risk and Responsibility in Chemical Research: The Case of Agent Orange", *HYLE: International Journal for Philosophy of Chemistry*, 2005, 11 (2), pp. 147-166.

Kirby, K. and F. A. Houle, "Ethics and the welfare of the physics profession", *Physics Today*, 2004, 57(11), pp. 42-46. http://dx.doi.org/10.1063/1.1839376

Kovac, J., "Gifts and Commodities in Chemistry", *HYLE: International Journal for Philosophy of Chemistry*, 2001, 7 (2), pp. 141-153.

Kovac, J., *The Ethical Chemist: Professionalism and Ethics in Science*, Pearson Prentice Hall, Upper Saddle River 2003.

Lynas, M., *Six Degrees. Our Future on a Hotter Planet*, National Geographic, Washington, DC, 2008.

Noyori, R. and J. P. Richmond, "Ethical Conduct in Chemical Research and Publishing", *Advanced Synthesis & Catalysis*, 2013, 355 (1), pp. 3–9.

Pearson, G. S. and Peter Mahaffy, "Education, outreach, and codes of conduct to further the norms and obligations of the Chemical Weapons Convention", *IUPAC Technical Report* 2006, Vol. 78, Issue 11, pp. 2169-2192. http://pac.iupac.org/publications/pac/pdf/2006/pdf/7811x2169.pdf

Royal Society of Chemistry, *Regulation of the profession and code of conduct.* http://www.rsc.org/images/code-of-conduct_tcm18-5101.pdf.

Schummer, J., "Ethics of Chemical Synthesis", *HYLE: International Journal for Philosophy of Chemistry*, 2001, 7 (2), pp. 103-124.

Segerstråle, U., "Good to the last drop? Millikan stories as 'canned' pedagogy", *Science and Engineering Ethics*, 1995, 1 (3), pp. 197-214.

Society of Environmental Toxicology and Chemistry (SETAC) (1994), *Pesticide Risk Assessment and Mitigation. Final Report of the Aquatic Risk Assessment and Mitigation Dialogue Group*. SETAC and SETAC Foundation for Environmental Education, SETAC Press, Pensacola, FL, 1994.

Viau, C., "Ethical Issues in Toxic Chemical Hazard Evaluation, Risk Assessment and Precautionary Communications", *General, Applied and Systems Toxicology*, 15 Dec 2009. http://onlinelibrary.wiley.com/doi/10.1002/9780470744307.gat162/abstract

Weart, S. R., *The Discovery of Global Warming*, Harvard University Press, Cambridge, MA, 2008.

Wylo, B. and M. Thomsen, "Should physics students take a course in ethics?—Physicists respond", *Science and Engineering Ethics*, 1998, 4 (4), pp. 473-486.

7.2 Journals, conferences and book series

Angewandte Chemie International Edition, WILEY-VCH Verlag, Online ISSN: 1521-3773.

Chemistry Education Research and Practice, Royal Society of Chemistry. http://pubs.rsc.org/en/journals/journalissues/rp#!recentarticles&all

HYLE: International Journal for Philosophy of Chemistry, HYLE Publications, Berlin, ISSN 1433-5158. – Special issues on ethics of chemistry: 2001, 7 (2); 2002, 8 (1).

Journal of Chemical Education, American Chemical Society, Division of Chemical Education and Publications Division, ISSN: 0021-9584.

Physics and Society, Forum on Physics and Society, American Physical Association. http://www.aps.org/units/fps/newsletters/

Physics Today, The American Institute of Physics.

Science and Engineering Ethics, Springer, ISSN: 1353-3452

Symposiums at the Chemistry Congresses of the European Association for Chemical and Molecular Sciences:

- Ethics, Chemistry and Education for the Environment, 3rd EuCheMS Chemistry Congress, Nürnberg (Germany), 31 August 2010;
- Ethics in Science - Chemistry and Ethics, 4th EuCheMS Chemistry Congress, Prague (Czech Republic), 29 Aug 2012.

Marshall Thomsen, a professor at Eastern Michigan University, runs a website with resources for ethical issues in physics: http://people.emich.edu/jthomsen/Ethics/EIPHome.htm