An Online Ethics Survey of CCC Members:

Noteworthy Findings

CCC Ethics Study # I

by

Robert McGinn
Lead CCC Ethics Investigator and Coordinator

December 2019

I. Introduction

In April of 2019, the author designed a questionnaire[1] for a planned online survey of members of UCSF's Center for Cellular Construction (CCC). The survey sought information about the views of CCC faculty, students, and post-docs about ethical issues related to their work. The hope was that the information obtained would be useful for, among other purposes, selecting topics and issues to be explored in a future CCC minicourse on ethics and responsible research and innovation. An application for approval to conduct the survey was submitted to the Human Research Protection Program of UCSF's Institutional Review Board (IRB) on May 17, 2019. The proposed survey received "Exempt Certification" on June 21, 2019.

II. Sample and Response Rate

The document that preceded the questionnaire described the uses to which the information obtained would be put, disclosed the (minimal) risks to respondents, assured respondent anonymity, and invited would-be respondents to give their consent to filling out the questionnaire. The document was uploaded to the Internet on June 27, 2019, and remained open through mid September 2019. In 2019, CCC had about 160 members,

[1] Reproduced in Appendix A.

mostly faculty, post-doctoral scholars, and graduate students. Shortly after the survey document was uploaded, the Center's director invited all CCC members to participate in the survey and provided a link to the questionnaire.

The questionnaire had two parts: A and B. Part A had 40 ítems (A1,…,A40), while Part B had 19 (B1,…,B19). Several items had subparts. For example, A21 had six subparts (A21/1,…A21/6) and B17 seven subparts (B17/1,…,B17/7).

The response rate for the questionnaire was approximately 25%. However, since the respondents self-selected, they do not comprise a probabilistically random sample of the population of all CCC members. Hence, one cannot assume that the group of 40 respondents[2] is representative of that population. In addition, the number of responses obtained was insufficient for cross-tabulation analysis to yield statistically

[2] The response data from two participants was deleted since each gave the same response to every question s/he answered in Part A.

significant conclusions. Nevertheless, frequency analysis of the response data yielded a number of suggestive and noteworthy findings.

III. Suggestive and Noteworthy Findings

1. "It is important that cellular engineering researchers consider ethical issues related to their work and its possible applications." (A7)

Finding: All 38 respondents *agreed* with the claim in A7, 33 (86.8%) of them *strongly*.

Discussion: This finding suggests that CCC researchers do not believe that considering such issues is a trivial matter or that it is okay for cellular-engineering (C-E) researchers to ignore such consideration. It also suggests that the respondents realize that C-E researchers themselves need to consider to such issues, rather than outsourcing such consideration to parties such as regulators, ethicists, politicians, and the public.

2. "If a cellular engineering researcher has reason to believe that her/his work will be applied in society so as to create a significant risk of harm to human beings, s/he has an ethical responsibility to alert appropriate parties in her/his research organization to the potential danger." (A14)

Finding: 35 (92.1%) of the 38 respondents *agreed* with the claim in A14, 30 (78.9%) of them *strongly*. Two respondents (5.3%) disagreed, one of them *strongly*, and one chose "don't know."[3]

Discussion: This is a striking finding because it shows that more than 9 of every 10 respondents agreed – most of them *strongly* – that under the stated condition, a C-E researcher has an ethical responsibility upstream to alert appropriate parties in her/his research organization that her/his work is likely to be applied downstream, in society, such that a significant risk of human harm results. This implies that for these respondents the ethical responsibilities of C-E researchers are *not* limited to avoiding the three most familiar forms of research misconduct: *fabrication*, *falsification*, and *plagiarism*. Rather, they believe that under certain conditions C-E researchers can also have an extra-lab ethical responsibility, one owed *to society at large,* to try (by alerting appropriate authorities) to prevent harms that they believe could result from application of their research work. The respondents who agreed with A14 clearly believe that although they are researchers, the macro-social context of their research work can engender an added ethical responsibility. Situating research work in its full

[3] Hereafter, "don't know" is sometimes abbreviated as "DK."

social context, from the micro context of the lab to the macro context of society at large, is important for identifying all of a researcher's ethical responsibilities.

3. "It is acceptable for a researcher with extensive experience in biosynthesis to take a shortcut that violates established lab safety procedures." (A11)

Finding: 31 of the 38 (81.6%) respondents to A11 *disagreed* with it, 23 (60.5%) of them *strongly*. Three respondents chose "DK."

Discussion: This finding suggests that most CCC researchers reject the notion that being a C-E researcher experienced in biosynthesis justifies her/him in violating well known lab safety procedures by taking shortcuts. This is a welcome result, especially given the pressure to rapidly get on with one's work that contemporary researchers can face. However, the fact that 4 respondents (10.5%) agreed with A11, although none strongly, is somewhat concerning. It suggests that efforts to refute the claim in A11 are in order.

4. "A cellular engineer whose research methods or practices unknowingly pose a risk to lab safety is blameless." (A10)

Finding: 33 (86.8%) of the 38 respondents *disagreed* with A10; 21 (55.3%) of them *strongly*.

Discussion: Encouragingly, the great majority of respondents *disagreed* with this proposition, a majority of them *strongly*. One respondent **did** agree *strongly* with the claim, indicating that s/he may not adequately realize that negligence, in the form of tolerating avoidable ignorance, can be a form of ethically blameworthy research misconduct as much as deliberately undertaken actions can. The ethical relevance of negligence in its various forms is a topic that could add value to future CCC educational events.

5. "The ethical issues related to cellular engineering research and its applications are no different than those related to other areas of engineering research and their respective applications." (A8)

6. "Some ethical issues related to cellular engineering research and its applications are unique to cellular engineering." (A20)

Finding: 13 of the 38 respondents (34.2%) to A8 *agreed* with it, 4 *strongly.* 20 (52.6%) *disagreed* and five (13.2%) chose "DK." 30 of the 38 respondents (78.9%) to A20 *agreed* with it; 13 *strongly*. 6 (15.8%) *disagreed* and 2 (5.3%) chose "DK."

Discussion: A8 is the virtually the *logical negation* of A20. Hence, in principle, the percentage of respondents to A8 who *agree* with its 'no different than' claim should be the same as the percentage of respondents

to A20 who *disagree* with its 'unique' claim. Similarly, the percentage of respondents to A8 who *disagree* with its 'no different than' claim should be the same as the percentage of A20 respondents who *agree* with its 'unique' claim. While **34.2%** of A8's respondents agreed with it, **21.1%** of A20's respondents disagreed with it. Moreover, while **52.6%** of A8's respondents disagreed with it, **79.4%** of A20's respondents agreed with it. These disparities suggest a non-trivial level of inconsistency in the responses to A20 and A8. Unfortunately, the questionnaire does not allow us to account for this intriguing phenomenon.

Regarding the view espoused by the 21.1% who *disagree* with A20's 'uniqueness' claim and the 34.2% who *agree* with A8's 'no different than' claim, it is important to note that just because none of the ethical issues raised in the field (F) of research under scrutiny is unique to F does **not** mean or imply that those issues are unimportant or justifiably disregarded. Old ethical wine in new technological bottles can still be worth exploring. In the author's experience, many students in engineering and science make precisely that assumption, and devalue the importance of considering ethical issues raised in F because they do not believe them to be qualitatively new.

7. “Applications of cellular engineering research to …X… will give rise to ethical controversy in society.” (A21/1-6)

Finding: The percentage of respondents who *agreed* that applications of cellular-engineering research in a particular area "will give rise to ethical controversy in society" was highest for the areas of **medical care** (88.9%; one DK) and **military affairs** (88.6%; two DKs). It was lowest for **manufacturing** (62.9%; three DKs) and **energy production** (62.8%; three DKs).

Discussion: Of the six application areas listed in the questionnaire for which responses were solicited, the level of agreement was highest for the **medical care** and **military affairs** fields, both involving matters of life and death. However, it is surprising that the percentage of respondents who “agree strongly” that applications of cellular engineering research in a certain area will give rise to ethical controversy in society was substantially greater for military affairs (71.1 %) than for medical care (55.3 %). What accounts for this disparity is not determinable from the survey.

Given the six listed application areas, it is not unexpected that the “agree” percentage was lowest for the **manufacturing** and **energy production** areas, since they are not immediately and directly linked to issues of life and death. Nevertheless, it is striking that the percentage of

respondents who agree that applications of C-E research in that area will give rise to ethical controversy in society exceeded 60% for *all six* areas. Most C-E researchers appear to believe that they are working in a potentially or inherently ethically controversial field.

8. "Study of ethical issues related to science and engineering should become a standard part of the education of future engineers and scientists." (A40)

Finding: 34 of the 35 respondents to A40 (97.1%) agreed with it, the other chose "DK." (Three respondents did not answer.) 28 (80%) of them agreed *strongly* that such study should become a standard part of the education of future technical professionals.

Discussion: It is remarkable that 97.1% of the respondents *agree* that study of ethical issues should become a standard feature of the education of future engineers and scientists, and almost as striking that 80% of the respondents answered "agree *strongly*." One possible explanation for those high percentages is that it is widely believed that ethical issues will appear with increasing frequency in engineering in the future, hence that it will become increasingly important for engineers be conversant with them and have a way to speak clearly about them with others.

Although indeterminable from this survey, it would be interesting to know whether these two levels – 97.1% and 80% -- are characteristic of the population of all CCC researchers and, more generally, the population of faculty and students in cellular engineering as a whole, not just the current sample of CCC respondents. It would also be interesting to know which if any fields or special areas of contemporary engineering, such as nanotechnology, artificial intelligence, neuroengineering, and robotics, would yield levels of "agree" and "agree strongly" responses comparable to or higher than those given for cellular engineering by the present CCC sample.

9. "Completing this questionnaire has heightened my awareness of ethical issues and responsibilities related to cellular engineering research and its applications." (A39)

Finding: 31 of the 36 (86.1%) respondents to A39 agreed with it; of those, 13 (36.1%) agreed *strongly*. (Four respondents did not answer.)

Discussion: About 6 of every 7 respondents *agreed* that doing the ethics questionnaire enhanced their awareness of ethical issues and responsibilities related to C-E research and its applications. That suggests that pondering and replying to the questionnaire items left respondents with the sense that their awareness of ethics as it relates to their work had

been deepened and/or broadened. These results – 86.1% and 36.1% -- indicate that many respondents believe they realized an intellectual benefit from having navigated the questionnaire.

10. Consider the following three scenarios and indicate the degree to which you agree with the ethical acceptability claim made in each:

    A. "Suppose cellular engineers learn how to redesign heirloom tomato seed cells so that the resultant seeds produce more, larger, and sweeter tomatoes than do normal seeds. It would be ethically acceptable for the cellular engineers involved to share their know-how with agriculture-related companies that have tomato-breeding programs and sell seeds to farmers and home gardeners." (A36)

    B. "Suppose cellular engineering researchers learn how to alter the designs of hawk embryo cells such that the resultant hawks can fly significantly faster and farther than is normally the case. It would be ethically acceptable for these engineers to offer their knowledge of how to alter such cells to companies wanting to sell the engineered hawk chicks to interested parties." (A37)

    C. "Suppose cellular engineers succeed in manipulating organelles in the cells of a human embryo such that the resultant human being had significantly improved memory function. It would be ethically acceptable for the engineers involved to offer this service to interested would-be parents who undergo in vitro fertilization." (A38)

Finding: Amongst the 35 respondents to A36, A37, and A38, the ethical acceptability of cellular *enhancement* was most widespread (62.9%) for the plant life/heirloom tomato example, considerably less widespread

(22.9%) for the non-human animal life/hawk embryo example, and least widespread -- in fact minimal (5.7%) -- for the human life/human embryo example.

Discussion: It is not surprising that, in the case of the human embryo example, all but two respondents viewed cellular enhancement as ethically unacceptable. But it is quite surprising to the author that a substantial majority deemed cellular enhancement ethically unacceptable in the case of the hawk-embryo example, and even more surprising that almost two fifths of the respondents deem cellular enhancement ethically unacceptable in the case of the heirloom-tomato example. It appears that most of the CCC members who responded to these scenarios have internalized the standard bioethical distinction between intervention for *therapeutic* purposes, deemed ethically acceptable, and intervention for *enhancement* purposes, deemed ethically unacceptable, and they have embraced this distinction *not just for interventions in human beings.* Exploration of the rationales for these beliefs might be worthwhile in the projected CCC ethics minicourse.

1

1. Questionnaire items with the **highest** variance values.

Finding: In order of *decreasing* variance, the four questionnaire items with the highest response variance values follow.

A. "It is ethically responsible for cellular engineers working on a novel engineered organism to base their estimate -- to be communicated to the public -- of the risk of harm the organism poses solely on two factors: the designs of the cells that make up the organism, and data about its behavior obtained from observations made in the cellular engineering lab." (A32) V = 2.03, D = -7

B. "A biological engineering team achieves full biosynthesis in yeast of an opioid painkiller, one previously derived from an alkaloid in the opium poppy. The researchers utilized enzyme discovery, enzyme engineering, and pathway and strain optimization to turn glucose into the opioid. Concerns about biohacking and the side effects of opioids notwithstanding, given the potential that this achievement opens up for biosynthesizing new drugs, it is ethically responsible for the researchers, without delay, to submit for publication in a leading scientific journal a manuscript detailing the methods and strains used to achieve the opioid biosynthesis." (A35) V = 1.92, D = -4

C. "A cellular engineering team has created a novel kind of cell, one intended to be part of a new organism to be released in the environment. While the new organism's future behavior in the environment is currently uncertain, its use is expected to realize desired benefits for society and create unintended risks. It is ethically acceptable for the team to move forward with using the new cell if a plausible case can be made that the benefits of the new organism will exceed its risks." (A33) V = 1.81, D = -7

D. A manuscript co-authored by several cellular-engineering researchers with different specialties is to be submitted for publication to a scholarly journal. The ethical responsibility of each co-author is just to ensure that the research underlying her/his own contribution to the manuscript used proper methods and reached correct conclusions. (A16) V = 1.65, D = 7

Discussion: Items A32, A35, A33, and A16 had the highest variance values. The "V" numbers after the texts of the items above are the standard statistical variance values. However, those V numbers reflect the "DK" responses given, scored as 5s. They thus arguably distort the variance values of the responses by distorting their means. To compensate for this, consider a new dependent variable, D, standing for "Divergence." D is the sum of the number of "agree strongly" and the number of "agree somewhat" responses, minus the sum of the number of "disagree strongly" and the number of "disagree somewhat" responses. Thus, "DK" responses do not enter into calculations of D values.

A D number that is small in absolute value corresponds to a set of responses which are relatively dispersed and spread out across the agree/disagree options. Put differently, small magnitude D values correspond to a divergent response set. In contrast, a D number that is large in absolute value corresponds to a set of responses which are quite or

very concentrated. In such cases the number of “agree strongly” and “agree somewhat” responses is considerably larger (or smaller) than the number of “disagree strongly” and “disagree somewhat” responses.

The high V and low D values of A32 suggest that responses to that item were widely distributed. Thus, a good number of respondents – the 11 who agreed with the claim in A32 -- apparently do not recognize that the risk of harm the posited novel engineered organism poses depends not just on the two cited factors (cell design and research lab measurements), but also on contingent features of the contexts in which the novel organism will be produced, regulated, used, and disposed of/recycled. In effect, A32 induced a fraction of the respondents to implicitly endorse an idealized, i.e., *decontextualized*, process of risk estimation. Such a process might well be incomplete, and its result misleading and ethically unacceptable to promulgate and rely upon.

A35’s high V and low D values suggest considerable dissensus over whether it would be ethically acceptable to publish the referenced dual-use- research paper *independently* of social conditions that, depending on their nature, could make doing so relatively safe or significantly risky.

A33's high V and low D values suggest similar dissensus about whether a favorable benefit-risk analysis for the new organism is sufficient to make moving forward with use of the novel kind of cell in it ethically acceptable. Respondents are significantly split on that question.

Finally, A16's similar V and D values suggest that the respondents are significantly split about whether the only ethical responsibility of each author of a paper born of collaborative research is to ensure that her/his own methods and conclusions are proper and valid.

With these findings in mind, it appears that four issues would make topics worth exploring in a potential CCC ethics minicourse: the factors to be taken into account in doing an ethically responsible risk estimates, the factors to be taken into account in deciding whether and when to publish the findings of a dual-use research project, the circumstances under which a favorable benefit-risk analysis might and might not be the last word in ethically responsible R&D, and the responsibilities incumbent upon each co-author of a paper based on collaborative research.

12. Questionnaire items with the **lowest** response variances.

Finding: The following three items had the lowest response variances, listed in order of *increasing* magnitude:

A. "It is important that cellular-engineering (CE) researchers consider ethical issues related to their work and its possible applications." (A7) V = .13, D = 38

B. "Study of ethical issues related to science and engineering should become a standard part of the education of future engineers and scientists." (A40) V = .19, D = 35

C. "The cellular engineering researcher has an ongoing obligation to be alert to ethical issues arising in and from her/his work." (A23) V = .19, D = 34

Discussion: the three items with the lowest variance values had large D values, thus exhibiting high levels of response concentration. As discussed earlier[4], the respondents agreed unanimously with the claim in A7. Moreover, 33 of the 38 respondents agreed *strongly* with it. Nor was there any respondent disagreement with the claim in A40, regarding beliefs about whether study of ethical issues related to science and engineering should be a standard part of the education of future engineers and scientists. However, the *ratio* of the number of "agree strongly" responses to the number of "agree somewhat" responses was bigger for A7 than for A40 (6.6 vs. 4.0). A23 had the same V value (.19) but a slightly smaller D value (34 vs. 35) than A40, because, one respondent disagreed with the

[4] See pp. 3-4.

claim in A23. In short, the degrees of concentration and convergence that the response sets to items A7, A40, and A23 exhibit are strikingly high.

Items **A5** (about the respondent 'taking ethics seriously') and **A30** (about the C-E researcher having an ethical responsibility to participate in public discussions of ethical issues related to cellular engineering research and its applications), both of which have low V values, elicited about as many 'agree responses'[5] as did A23 and A40. However, the **ratios** of the number of "agree strongly" responses to the number of "agree somewhat" responses for A5 and A30 (both close to 1.0) were *much smaller* than those for A23 and A40, since the respondent sets for A5 and A30 contained almost equal numbers of "agree somewhat" and "agree strongly" responses. Thus, even though they had comparable V values, their close-to--1 ratios indicate that neither A5 nor A30 had response sets as concentrated and convergent on one response as did A23 and A40. The "agree strongly" support A5 and A30 elicited was not nearly as widespread. This is why the author chose not to included them on the list of the items

[5] That is, the *sum* of the number of "agree somewhat" responses and the number of "agree strongly" responses.

with the three lowest response variances.

13. Safety cultures of CCC-affiliated research labs

    A. "All CCC research labs with which you are familiar have strong safety cultures." (A26)

    B. "You are familiar with a CCC research lab that does not have a strong safety culture." (A34)

Finding: Of the 35 respondents to A26, 22 (62.9%) **agreed** with it; the other 13 (37.1%) chose "DK." Of the 22 respondents who agreed, 16 (72.7%) chose "agree strongly." Of the 35 respondents to A34, 23 (65.7%) **disagreed** with it; the other 12 (34.3%) chose "DK." Of the 23 respondents who disagreed, 20 (87%) chose "disagree strongly."

Discussion: Deliberately positioned at some distance from A26 in the questionnaire, A34 is basically the *logical negation* of A26, and vice versa. Hence, in principle, one would expect that those who agreed with A26 would disagree with A34 and those who agreed with A34 would disagree with A26. Unlike the inconsistent response sets for the logically complementary item pair A8 ('no different than') and A20 ('unique'), discussed on pp. 6-8, the responses to A26 and A34 were *virtually perfectly consistent*. They suggest that those who agreed or disagreed harbor little if

any doubts about the strength of the safety cultures of CCC-affiliated research labs. This is a promising finding.

But why did more than a third of the respondents to both A26 and A34 choose “don’t know”? Did they believe they lacked empirical evidence to agree or disagree to any degree? Did they not clearly understand what is meant by a “safety culture”? Was there some other reason? Unfortunately, the questionnaire does not permit us to shed light on this matter.

IV. Conclusion

From an ethics perspective, while one wishes the survey response rate had been significantly higher, there is much that is encouraging about the results of the CCC ethics questionnaire. Unless the views expressed by the sample‘s respondents are substantially unrepresentative of those of the population of all CCC members, the findings suggest that, among other things, the great bulk of CCC researchers believe that it is important that C-E researchers consider ethical issues related to their work; do not believe that causing a risk of harm through negligent lack of knowledge is ethically blameless; and agree that if a C-E researcher has reason to believe upstream that the results of their research are likely to be applied downstream in society such that they pose a significant risk of harming

humans, then s/he has an ethical responsibility to alert appropriate authorities in their research organizations about the situation.

On the other hand, the results obtained also suggest that CCC researchers have quite divergent views about some issues embedded in various questionnaire items, for example,

- whether it is ethically acceptable for a researcher to publish at will a paper that reveals critical details of dual-use research, such as opioid biosynthesis;

- whether it is ethically acceptable to proceed to use a novel kind of cell if a plausible case can be made that the benefits of a new organism that incorporates it will exceed its risks;

- whether it is ethically acceptable to base a risk estimate of an engineered organism solely on the designs of its constituent cells and measurements of its behavior in the research laboratory; and

- what is the full range of ethical responsibilities of each co-author of a paper reporting the results of a collaborative research endeavor.

Strongly divergent CCC researcher views about such issues suggest that it might be useful to explore whether cellular engineering and the contexts in which its products are likely to find application call for revisiting and revising certain accepted research-related practices and ideas, and the scopes of their applicability. Targets of opportunity germane to CCC would include publication of dual-use research results, co-authors' individual

responsibilities in the publication of collaborative research papers, relevant risk-estimate factors, and the reliance on certain accepted techniques, e.g., cost-benefit-risk analysis, in critical professional decision-making contexts. The ethical justification for such examinations would be to try to avoid causing harms that might flow from adhering to standard practices, ideas, or techniques, or from utilizing them in unchanged forms, universally and unconditionally, in novel situations. Such explorations are potential foci for the envisioned CCC ethics minicourse.

END

Appendix A

Ethics Questionnaire

CENTER FOR CELLULAR CONSTRUCTION

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

Part A: CCC RESEARCHER VIEWS ABOUT ETHICAL ISSUES RELATED TO THEIR WORK (15 MINUTES)

Using the following scale, for each statement select the number or two-letter abbreviation that most closely corresponds to your position about that statement.

strongly disagree = 1	somewhat disagree = 2	somewhat agree = 3	strongly agree = 4	don't know = DK	not applicable = NA

A1. There are significant ethical issues related to cellular engineering.
1 2 3 4 DK

A2. The ethical dimension of cellular engineering is much less important than its technical dimension. 1 2 3 4 DK

A3. I am interested in ethical issues related to cellular engineering.
1 2 3 4 DK NA

A4. I am knowledgeable about ethical issues related to cellular engineering.
1 2 3 4 DK NA

A5. I take ethical issues related to cellular engineering seriously.
1 2 3 4 DK NA

A6. I possess ideas and skills that enable me to thoughtfully consider ethical issues related to cellular engineering. 1 2 3 4 DK NA

A7. It is important that cellular engineering researchers consider ethical issues related to their work and its possible applications. 1 2 3 4 DK NA

strongly disagree = 1	somewhat disagree = 2	somewhat agree = 3	strongly agree = 4	don't know = DK	not applicable = NA

A8. The ethical issues related to cellular engineering research and its applications are no different than those related to other areas of engineering research and their respective applications. 1 2 3 4 DK NA

A9. It is important that the public be involved in consideration of ethical issues related to cellular engineering. 1 2 3 4 DK NA

A10. A cellular engineer whose research methods or practices unknowingly pose a risk to lab safety is blameless. 1 2 3 4 DK

A11. It is acceptable for a researcher with extensive experience in biosynthesis to take a shortcut that departs from an established lab safety procedure. 1 2 3 4 DK

A12. It is the ethical responsibility of the cellular engineering lab manager, not the individual cellular engineering researcher, to try to stop another such researcher from departing from published lab safety rules. 1 2 3 4 DK

A13. It is ethically acceptable for a researcher to exaggerate the potential benefits of an innovative cellular engineering project s/he seeks to pursue in order to increase its chances of being funded. 1 2 3 4 DK

A14. If a cellular engineering researcher has reason to believe that her/his work will be applied in society so as to create a significant risk of harm to human beings, s/he has an ethical responsibility to alert appropriate parties in her/his research organization to the potential danger. 1 2 3 4 DK

A15. Once a research paper based on experimental lab data has been published in a scholarly journal, it is ethically acceptable for its author(s) to discard the original data records. 1 2 3 4 DK

strongly disagree = 1	somewhat disagree = 2	somewhat agree = 3	strongly agree = 4	don't know = DK	not applicable = NA

A16. A manuscript co-authored by several cellular engineering researchers with different specialties is to be submitted for publication in a scholarly journal. The ethical responsibility of each co-author is just to ensure that the research underlying her/his own contribution to the manuscript used proper methods and reached correct conclusions. 1 2 3 4 DK

A17. A cellular engineering researcher knows from her/his lab experience that each of several kinds of cells is safe to synthesize. It is ethically acceptable for her/him to assume that any organism producible from those cells is safe to synthesize in the lab. 1 2 3 4 DK

A18. It is ethically acceptable for a cellular engineering researcher to withhold commercially significant findings from a scholarly publication at the request of the company that funded or is funding her/his research. 1 2 3 4 DK

A19. A researcher has an ethical responsibility to not exaggerate the importance of her/his new cellular engineering achievement when contributing to mass-media coverage of it. 1 2 3 4 DK

A20. Some ethical issues related to cellular engineering research and its applications are unique to cellular engineering. 1 2 3 4 DK NA

strongly disagree = 1	somewhat disagree = 2	somewhat agree = 3	strongly agree = 4	don't know = DK	not applicable = NA

A21. For each area, select the number or abbreviation that most closely corresponds to your position about the statement that applications of cellular engineering research to that area will give rise to ethical controversy in society:

a. military affairs	1	2	3	4	DK
b. medical care	1	2	3	4	DK
c. manufacturing	1	2	3	4	DK
d. energy production	1	2	3	4	DK
e. food production	1	2	3	4	DK
f. environmental remediation	1	2	3	4	DK

A22. A cellular engineering researcher has reason to believe that a federal regulatory agency's decision to release a new biosynthesized product to market may pose a significant unrecognized risk to public health, safety, or welfare. However, s/he does not have an ethical responsibility to make her/his concern known to the agency or the public. 1 2 3 4 DK

A23. The cellular engineering researcher has an ongoing obligation to be alert to ethical issues arising in and from her/his work. 1 2 3 4 DK NA

A24. To foster responsible conduct of research and innovation in a cellular engineering lab, lab directors and managers should allow individual researchers to regulate themselves, rather than establish and promulgate clear guidelines for proper research and innovation practice.

1 2 3 4 DK

strongly disagree = 1	somewhat disagree = 2	somewhat agree = 3	strongly agree = 4	don't know = DK	not applicable = NA

A25. Based on current understanding, a cellular engineer believes that her/his research can reasonably be anticipated to provide knowledge, information, products, or technologies that lend themselves to two uses. One would significantly benefit public health, safety, or welfare, while the other could pose a significant threat, with broad potential consequences, to public health, safety, or welfare. This cellular engineer's only ethical responsibility in relation to this search is to ensure that her/his methods, data gathering, reasoning, calculations, and conclusions are valid/correct. 1 2 3 4 DK

A26. All CCC research labs with which you are familiar have strong safety cultures. 1 2 3 4 DK

A27. A cellular engineering researcher has reason to believe that a journalist who wants to interview her/him about her/his recent innovative achievement will sensationalize or oversimplify it in a planned mass-media news article. The researcher has an ethical responsibility to not do anything that would lend credibility to the planned article. 1 2 3 4 DK

A28. A cellular engineering researcher has reason to believe that a government regulatory agency's decision about a new biosynthesized product was made on political-economic grounds. The researcher has an ethical responsibility to bring that situation to public attention. 1 2 3 4 DK

A29. A researcher, serving as an independent expert witness on cellular engineering in a major patent trial, hears the judge make a statement about cellular engineering that the researcher knows is false and misleading. The researcher believes that, left uncorrected, the statement could well significantly alter the trial's outcome. Nevertheless, the researcher does not have an ethical responsibility to refute the judge's statement unless s/he is directly asked about it in her/his formal testimony. 1 2 3 4 DK

strongly disagree = 1	somewhat disagree = 2	somewhat agree = 3	strongly agree = 4	don't know = DK	not applicable = NA

A30. Cellular engineering researchers have an ethical responsibility to participate in public discussions of ethical issues related to cellular engineering research and its applications. 1 2 3 4 DK

A31. A respected cellular engineer researcher, Smith, reads an article in the science section of an influential national newspaper that s/he believes seriously misrepresents the nature and importance of the research achievement of another cellular engineer. Smith does not have an ethical responsibility to try to remedy the public misunderstanding caused by the article. 1 2 3 4 DK

A32. It is ethically responsible for cellular engineers working on a novel engineered organism to base their estimate -- to be communicated to the public -- of the risk of harm the organism poses solely on two factors: the designs of the cells that make up the organism, and data about its behavior obtained from observations made in the cellular engineering lab. 1 2 3 4 DK

A33. A cellular engineering team has created a novel kind of cell, one intended to be part of a new organism to be released in the environment. While the new organism's future behavior in the environment is currently uncertain, its use is expected to realize desired benefits for society and create unintended risks. It is ethically acceptable for the team to move forward with using the new cell if a plausible case can be made that the benefits of the new organism will exceed its risks. 1 2 3 4 DK

A34. You are familiar with a CCC research lab that does not have a strong safety culture. 1 2 3 4 DK

strongly disagree = 1	somewhat disagree = 2	somewhat agree = 3	strongly agree = 4	don't know = DK	not applicable = NA

A35. A biological engineering team achieves full biosynthesis in yeast of an opioid painkiller, one previously derived from an alkaloid in the opium poppy. The researchers utilized enzyme discovery, enzyme engineering, and pathway and strain optimization to turn glucose into the opioid. Concerns about biohacking and the side effects of opioids notwithstanding, given the potential that this achievement opens up for biosynthesizing new drugs, it is ethically responsible for the researchers, without delay, to submit for publication in a leading scientific journal a manuscript detailing the methods and strains used to achieve the opioid biosynthesis. 1 2 3 4 DK

A36. Suppose cellular engineers learn how to redesign heirloom tomato seed cells so that the resultant seeds produce more, larger, and sweeter tomatoes than do normal seeds. It would be ethically acceptable for the cellular engineers involved to share their know-how with agriculture-related companies that have tomato-breeding programs and sell seeds to farmers and home gardeners.
1 2 3 4 DK

A37. Suppose cellular engineering researchers learn how to alter the designs of hawk embryo cells such that the resultant hawks can fly significantly faster and farther than is normally the case. It would be ethically acceptable for these engineers to offer their knowledge of how to alter such cells to companies wanting to sell the engineered hawk chicks to interested parties. 1 2 3 4 DK

A38. Suppose cellular engineers succeed in manipulating organelles in the cells of a human embryo such that the resultant human being had significantly improved memory function. It would be ethically acceptable for the engineers involved to offer this service to interested would-be parents who undergo in vitro fertilization.
1 2 3 4 DK

A39. Completing this questionnaire has heightened my awareness of ethical issues and responsibilities related to cellular engineering research and its applications.
1 2 3 4 DK NA

A40. Study of ethical issues related to science and engineering should become a standard part of the education of future engineers and scientists.

1 2 3 4 DK

PART B: INFORMATION ABOUT THE CCC RESEARCHER (5 MINUTES)

B1. Age (in years):

◎ < 18
◎ 18-22
◎ 23-26
◎ 27-30
◎ 31-40
◎ 41-50
◎ 51-60
◎ 61-70
◎ > 70

B2. Sex:

◎ female
◎ male
◎ decline to state

B3. Citizenship:

◎ U. S. A.
◎ another country
◎ permanent U.S. resident

B4. Race/ethnicity:

◎ American Indian/Alaskan Native
◎ Asian
◎ Black/African American
◎ Hispanic/Latino
◎ multiple-race
◎ Native Hawaiian/Other Pacific Islander
◎ White, Non-Hispanic
◎ decline to state

B5. Native language(s): (click the applicable button or buttons)

◎ English
◎ a language other than English
◎ two languages other than English

B6. Education: (click the button next to your highest completed degree)

◎ high school diploma or equivalent
◎ associate's degree (A.A., A.S.) or equivalent
◎ bachelor's degree (B.A., B.S., B.Eng.) or equivalent
◎ master's degree (M.A., M.S., M.Eng.) or equivalent
◎ Ph.D. degree or equivalent
◎ other (please specify) _____

B7. Occupation: (click the button next to the word or phrase closest to what you perceive as your occupation)

◎ scientist
◎ more scientist than engineer
◎ equally scientist and engineer
◎ more engineer than scientist
◎ engineer
◎ educator
◎ other (please specify): _____

B8. Organization: (click the button next to the kind of organization with which you are primarily affiliated)

◎ academic
◎ governmental
◎ business/industrial
◎ other (please specify) :_____

B9. Current position:

◎ undergraduate student
◎ graduate student
◎ postdoctoral scholar ("postdoc")
◎ faculty member
◎ researcher in a university
◎ researcher in a business/industrial firm
◎ researcher in a government facility
◎ supervisor of a research group
◎ other (please specify): _____

B10. Have you ever taken a course in which ethical issues closely related to science, technology, and/or engineering were discussed?

◎ yes (If you clicked "yes," continue to item #11.)
◎ no (If you clicked "no," skip to item #14.)

B11. Recall the course -- hereafter: "C" -- you took which had the most discussion of such ethical issues. For each of the following four statements about C, click the button next to the number that corresponds most closely to your position on it:

In course C, treatment of ethical issues related to science, technology, and/or engineering was…	strongly disagree = 1	somewhat disagree = 2	somewhat agree = 3	strongly agree = 4
a. frequent	◎1	◎2	◎3	◎4
b. in-depth	◎1	◎2	◎3	◎4
c. intellectually stimulating	◎1	◎2	◎3	◎4
d. useful preparation for addressing ethical issues you might encounter in your technical career	◎1	◎2	◎3	◎4

B12. What kind of course was C? (click one)

◎ a general ethics course, like those taught in most college/university philosophy departments
◎ a specialized ethics course, focused on ethics issues closely related to science, technology, and/or engineering
◎ a technical science or engineering course, with brief treatment or occasional discussion of ethical issues
◎ another kind of course? (please specify): _____

B13. Was course C… (click one)

◎ required for your major in a field of science or engineering?
◎ required for your major in a field outside science and engineering?
◎ required by your college/university but not by your major?
◎ taken to meet a requirement established by a government agency?
◎ optional, i.e., not required?

B14. In what general area of study is your highest degree? (click one)

◎ physical science
◎ life science
◎ formal science (logic, mathematics, statistics, decision theory, systems theory, theoretical computer science, information theory, etc.)
◎ social or behavioral science
◎ engineering
◎ other (please specify: _____)

B15. In that general area, in what specific discipline (e.g., biology, bioengineering, chemistry, biochemistry, etc.) is your most advanced degree?

Specific discipline: _____.

B16. At this point in your studies or career, to what extent is cellular engineering the focus of your research? Cellular engineering is…(click one)

not at all a focus of your research	a secondary or minor focus of your research	the co-equal focus (with another area) of your research	the primary or major focus of your research	the only focus of your research
= 1	= 2	= 3	= 4	= 5
◎1	◎2	◎3	◎4	◎5

B17. In the past, how frequently have you reflected on/thought about ethical issues or concerns involving…(in each row, click the button next to the number that most accurately applies to you)

	never = 1	rarely = 2	sometimes = 3	often = 4
a. researcher lab practices?	◎1	◎2	◎3	◎4
b. researcher conduct with students, supervisees, or lab staff?	◎1	◎2	◎3	◎4
c. researcher conduct in the publication process?	◎1	◎2	◎3	◎4
d. researcher conduct in communicating with the public?	◎1	◎2	◎3	◎4
e. researcher interactions with institutions such as government, business, the legal system, and the mass media?	◎1	◎2	◎3	◎4
f. applications of research and their effects on society?	◎1	◎2	◎3	◎4
g. applications of research and their effects on the natural environment?	◎1	◎2	◎3	◎4

B18. In your interactions with CCC researchers, how frequently have ethical issues or concerns related to cellular engineering been discussed? (click one button)

never = 1	rarely = 2	sometimes = 3	often = 4
◎1	◎2	◎3	◎4

Note: if you clicked button "◎1", skip to #20; otherwise, continue to #19.

B19. What was the position of the CCC work colleague with whom you've talked the most about ethical issues related to cellular engineering? (click one)

◎ faculty director of a research lab
◎ managing director of a research lab
◎ lab staff scientist or engineer
◎ lab technician
◎ research scientist or engineer
◎ post-doctoral researcher
◎ graduate student researcher
◎ faculty advisor
◎ other position (please specify: _____)

◎ I have never talked with a CCC work colleague about ethical issues related to cellular engineering.

* * *

Thank you for completing the 2019 CCC Ethics Questionnaire!