Ethical Considerations for Living Organisms Found Off-Planet or Created:
Ideas from Astrobiologists and Computer Scientists

Daniel S. Helman

Submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
from
Prescott College
in
Sustainability Education

May, 2017

Dale Patterson, Ph.D.

Committee Member

Gerard A. J. M. Jagers op Akkerhuis, Ph.D. Ph.D.

Committee Member

Pramod Parajuli, Ph.D.

Committee Chair

Henderson James Cleaves II, Ph.D.

External Reader

ABSTRACT

Prudence demands a pre-contact appraisal of ethical requirements towards living organisms as planetary science and astrobiology continue to move forward. Likewise, advances in artificial intelligence may mean that it will be necessary to have ethical guidelines in place for machine life. A novel framework for studying complementary ethical perspectives is presented along with results obtained by questionnaire and discussion with astrobiologists and computer scientists currently working in these areas. Outcomes include promoting the work of these professionals and their self-reflection, plus recommendations for policy-makers and relevant lesson plans for the classroom, plus the following inferences: Ethical perspectives based on personal, social, cultural, ecological, or quantitative themes may be orthogonal to each other. Moreover, psychometric analysis can be applied in a way that divides people into groups, and this analysis may create further social division. Technological issues such as the development of autonomous machines or discovering extraterrestrial life forms come with a responsibility that is parallel to the care that creating offspring engenders—and a more global discussion is warranted. Notwithstanding, innovation in information technology is associated with a flowering of imaginative ethical considerations that predate some of the technologies that they address. These imaginative ethics may become superfluous with time, whereas innovations in technology that impact the physical environment more directly often predate the development of relevant ethics. These relevant ethics address challenges only in hindsight. Thus, machine life and extraterrestrial life are likely to have different ethical trajectories.

Keywords: astrobiology, planetary science, origin of life, artificial life, machine life, ethics of science, complementary ethical perspectives, multiple-criteria analysis, science policy, STEM education

ACKNOWLEDGEMENTS

The work at hand could not have been undertaken without very great help and generosity from many communities and their members, for which I will be grateful for years to come. And, of course, love always to my parents.

Copyright © 2017 Daniel S. Helman Los Angeles, California
All rights reserved.

No part of this dissertation may be used, reproduced, stored, recorded, or transmitted in any form or manner whatsoever without written permission from the copyright holder or his agent(s), except in the case of brief quotations embodied in the papers of students, and in the case of brief quotations embodied in critical articles and reviews.

Instructors and students of U.S. accredited nonprofit educational institutions may—in compliance with certain stipulations—use, display and/or perform in a classroom environment any copyright-protected material or work without seeking the copyright holder permission normally required under U.S. copyright law. See Title 17 of the United States Code.

For all questions regarding reuse or permissions, write to

danielhelmanteaching@yahoo.com

TABLE OF CONTENTS

CHAPTER I: INTRODUCTION.....	11
Statement of the Problem.....	13
Purpose of This Study.....	14
Research Questions.....	14
Hypotheses.....	15
Theoretical Frameworks.....	15
Context of the Study.....	16
Overview of Methods.....	16
Significance of the Study.....	17
Specific Outcomes of the Research.....	19
Background and Role of the Researcher.....	20
Definition of Terms.....	21
Limitations and Delimitations.....	22
Summary.....	23
CHAPTER II: METHODS.....	24
Overview of Purpose and Research Questions.....	25
Methods.....	26
Sample.....	26
Data Collection Protocols and Procedures.....	30
Data Analysis and Procedures.....	32
Critical Reflection on the Research Design.....	32
Summary.....	34

CHAPTER III: LITERATURE REVIEW.....	35
Method.....	46
Case Studies.....	53
1. Ozone.....	53
Summary.....	53
Ethical question.....	53
2. GMOs in agriculture.....	55
Summary.....	55
Ethical question.....	55
3. Climate change.....	57
Summary.....	57
Ethical question.....	58
4. Astrobiology.....	60
Summary.....	60
Ethical question.....	60
5. Machine life.....	62
Summary.....	62
Ethical question.....	62
Discussion.....	64
CHAPTER IV: DATA AND ANALYSIS.....	67
Skype Group Discussions.....	67
1. Content Notes.....	68
First discussion.....	68

Second discussion.....	70
Third discussion.....	71
Summary.....	72
2. Reflection Notes.....	72
Impression one.....	72
Impression two.....	72
Impression three.....	73
Impression four.....	74
Impression five.....	75
Summary.....	76
3. Mathematical Reflection Notes.....	76
Summary.....	77
Word Count Validation.....	78
Questionnaire.....	83
Data Analysis.....	83
Results.....	84
Occurrence of the complementary ethical perspectives.....	85
Refining the ethical framework.....	91
Science, astrobiology, and machine life.....	95
1. Career interest.....	95
2. What is science?.....	96
3. Consciousness.....	97
4. Agency in artificial intelligence (AI) systems.....	97

5. Mineralogy.....	97
6. Thermodynamics.....	98
7. Interstellar medium.....	98
8. Genetics.....	98
9. Evolution.....	98
10. Development.....	98
11. Exoplanetary atmospheres.....	98
12. Chirality.....	99
13. Living in space.....	99
14. Nature of life.....	99
Suggested ethics.....	101
Validation of the Questionnaire Data Analysis.....	102
Occurrence of the complementary ethical perspectives.....	103
1. Kantian ethics.....	103
2. Ethics of care.....	105
3. Aesthetics.....	105
4. Evolutionary ethics.....	108
5. Opposed to evolutionary ethics.....	110
6. Land-based ethics.....	110
7. Utilitarian ethics.....	112
8. Opposed to utilitarian ethics.....	112
9. Pragmatic ethics.....	112
Refining the ethical framework.....	115

ETHICS, ASTROBIOLOGY & MACHINE LIFE	10
Science, astrobiology, and machine life.....	115
Suggested ethics.....	116
Recommendations for Policy Makers.....	116
Lesson Plans.....	119
Summary.....	120
CHAPTER V: DISCUSSION AND CONCLUSIONS.....	123
Complementary Ethical Perspectives.....	123
Personality Differences and Competition.....	126
Parental Responsibilities Towards Machine Life.....	128
Information Technology is Distinct.....	129
Conclusion.....	132
REFERENCES.....	133
APPENDIX A: GLOSSARY.....	152
APPENDIX B: CONTACT LETTER, INFORMATION ABOUT THE RESEARCH, FAQS, AND CONSENT FORM.....	154
APPENDIX C: QUESTIONNAIRE AND GROUP DISCUSSION QUESTIONS.....	159
APPENDIX D: QUESTIONNAIRE RESPONSES.....	165
APPENDIX E: RECOMMENDATIONS FOR POLICY MAKERS.....	205
APPENDIX F: LESSON PLANS.....	212
APPENDIX G: ADDITIONAL REFLECTIONS.....	223

CHAPTER I: INTRODUCTION

There are seven subjects of study in the classical liberal arts: the quadrivium of arithmetic, geometry, music, and astronomy, and the trivium of grammar, rhetoric, and logic (McLuhan, 1974). Liberal is used here as the mind is meant to be liberated by their study. Practical arts are numerous, and their application is more external. Liberal arts are also numerous, yet their purpose is still to liberate. The term educate has the root *-duc-* that is shared with the English term *duke*, a leader. To educate someone is to lead them out.

Currently there are many more than seven liberal arts in academic practice, and the sciences are often separated out and called sciences or natural sciences rather than liberal arts. The pedigree of their division is old (Conrad, 2014). Academic divisions are not set in stone, and researchers may work in related fields. Difficulties in securing this kind of cross-over are not uncommon, however. To teach in a different field may require transcripts with two years of graduate-level coursework in that field (Russell, 2012). The use of language between fields is often rich with different terminology. Barriers for communication exist (Harley et al., 2010). Yet, because the language used in different fields is often fundamentally different, the conceptualization between fields is generally distinct.

Biology, astronomy, and geology are connected in an area called astrobiology, which is the study of life on other planets (Des Marais et al., 2008). Knowledge of chemistry and other arts is useful in looking for self-sustaining chemical systems that are capable of undergoing Darwinian evolution—the NASA definition for life (Mullen, 2013). Likewise, a chemist may search out an autocatalytic set of chemistries that can act

in a geothermal region, or a biologist may look for amphiphilic compounds acting as proto-cell membranes. Inherent curiosity related to evolutionary processes, and especially Darwinian evolution is present inherently in attempts to clarify specific mechanisms for heredity, environmental response, endosymbiosis, signaling, etc.

Machine learning is an offshoot of a computational learning theory within computer science, and the study of evolutionary algorithms, a subset of machine learning, is applied to many real-world problems especially those relating to multiple criteria, for example, language and image recognition, forecasting, economic optimization (e.g., stock market strategies), etc. (Back et al., 1997; Goldberg & Holland, 1988). Much of the technological world depends upon machine learning. Genetic algorithms and neural nets may have taken inspiration from biological forms, but it is society and economics that shape the application of these now-pervasive machine learning techniques for the betterment of humanity (Back et al., 1997).

As both the fields of astrobiology and computer science are interested in evolutionary processes, the author asserts that benefit could be gained by making some of the thoughts of each party more accessible to the other. Life and technology approach organisms from different angles, as biology and chemistry have arisen from different applications: the one involved in how organisms shape the world, the other in the roles of molecules in the interaction, combination, and transformation of materials and systems. Researchers in astrobiology and computer science both anticipate paradigm-shifting discoveries: extraterrestrial life in the former field, and artificial life in the latter (Cavicchioli, 2004; Varela & Bourguine, 1992). Gathering survey data related to the work and thoughts of researchers in these fields and leading online discussion is meant as a

service to each field. Analyzing that data and deducing from it different ethical considerations that may be present is also meant as a service to each field and the world at large.

The tack that is taken is one of respect—that there may be different ethical considerations and perspectives present in the language of these researchers, and that these different perspectives ought to be highlighted not as a way of finding a single best solution, but rather as a means of promoting dialogue and mutual understanding. To this end a series of exercises looking at comparative ethical frameworks were developed and promoted. Their utility was explored both for classroom and policy contexts.

This chapter includes a statement of the problem, a description of the purpose of the study, research questions, hypotheses, theoretical frameworks, and of the context of the study, an overview of methods, a description of the significance of the study, specific outcomes of the research, the background and role of the researcher, a definition of terms, limitations and delimitations, and a summary. As it is an *introduction* it is meant to *lead into* the research. It is a digest, a series of short pieces.

Statement of the Problem

The problem is twofold: (a) astrobiologists and computer scientists are working towards finding extraterrestrial life and artificial life, respectively. Their work deserves a renewed interest in an ethical dimension related to it, especially before these discoveries are made. The previous statement implies that there is a need to fill, namely, that more data would be useful. Likewise, (b) these fields are widely separated. Astrobiologists and computer scientists do not always have enough opportunities to share their thoughts with

each other. The excitement of sharing ideas may lead to new research insights for study participants.

Purpose of This Study

The purpose of this study is twofold: (a) to develop insight into ethical considerations that astrobiologists and computer scientists may have about their work so that this may be made available for society; and (b) to promote progress in astrobiology and computer science.

The practical aim of this study is likewise twofold: (a) to gather some ideas from astrobiologists and computer scientists about their work including information related to ethical perspectives; and (b) to allow astrobiologists and computer scientists some opportunities to share their ideas.

Research Questions

The research questions are fourfold:

1. What are ethical considerations that astrobiologists hold about their work?
2. What are ethical considerations that computer scientists involved in artificial life or computational intelligence hold about their work?
3. What examples of lesson plans might be developed to teach aspects of astrobiology or computer science related to insights gathered from the ideas expressed by astrobiologists and computer scientists, respectively?
4. What policy recommendations in the realm of ethics can be made related to the emerging work of astrobiologists and computer scientists involved in artificial life or computational intelligence?

Hypotheses

For the research questions above, following the same numbering as above:

1. It is likely that such insights will be found.
2. It is likely that such insights will be found.
3. It is likely that such lesson plans will be developed.
4. It is likely that such policy recommendations will be developed.

Concerning ethics, not following the above numbering system:

1. Astrobiologists and computer scientists will express role-based evaluations of what is important to them personally and professionally.
2. Astrobiologists and computer scientists will express utilitarian evaluations of what is important to them personally and professionally.
3. The evaluations expressed by astrobiologists and computer scientists will show a mix of ethical considerations that can be distinguished into short-term and long-term frameworks.
4. Role-based evaluations will conflict with utilitarian evaluations.
5. Short-term considerations will conflict with long-term considerations.

Theoretical Frameworks

The theoretical frameworks are constructivist:

1. A constructivist framework was used for the purposes of gathering survey data and facilitating online Skype discussions.
2. A constructivist framework was used for the purposes of analyzing the data gathered.

3. A pedagogical framework based on constructivism was used for the creation of the lesson plans.
4. A constructivist framework was used for the purpose of communicating ethical considerations to policy makers.

Context of the Study

Several contexts overlap in this study:

1. This research is conducted in an academic context.
2. Research participants come from academia and industry.
3. Lesson plans were designed for use in primary, secondary, or tertiary classrooms, or for adult school, or for other public settings, such as museums or summer camps. The process of designing these was not predetermined. The work emerged after the author read and analyzed the data generated in the study.
4. Policy recommendations were tailored to international contexts, and to various levels of government or other institutions. The process of designing these was not predetermined. The work emerged after the author read and analyzed the data generated in the study.

Overview of Methods

The methodology of the study is qualitative and specifically draws on a general social science approach. The following research methods were used to gather data:

1. Questionnaire.
2. Skype group discussion facilitation.

The data are in the form of:

1. Text generated by the participants.

2. Notes and reflections generated by the author after the Skype discussions.

The data analysis followed an emergent process and included tests for validity and consistency.

Significance of the Study

The study impacts a variety of dimensions, including:

1. The personal and professional lives of researchers in astrobiology and computer science.
2. The personal and professional lives of people who interact with these researchers.
3. The personal and professional lives of teachers who use the resulting lesson plans.
4. The personal and professional lives of students taught using these lesson plans.
5. The personal and professional lives of policy makers in various fields who interact with the policy recommendations.
6. The personal and professional lives of people affected by policy made by these policy makers.
7. The personal and professional life of the author.
8. The personal and professional lives of people who interact with the author.
9. The personal and professional lives of the dissertation committee members.
10. The personal and professional lives of people who interact with the committee members.
11. The personal and professional lives of people who read the finished dissertation.

These impacts may influence or have influenced a variety of institutions, including:

1. Colleges and universities.
2. Corporations and other industrial institutions.

3. Schools and other educational and social institutions.
4. Governmental bodies.

The fields of study that may be influenced or may have been influenced include:

1. Astrobiology, the study of the origin of life, and synthetic biology.
2. Artificial life, multi-agent systems, robotics, machine learning, computational intelligence, artificial intelligence, genetic algorithms, evolutionary algorithms, brain-computer interfaces, machine consciousness, meta-learning, natural language processing, computational linguistics, and affective computing.
3. Pedagogy.
4. Politics and the study of ethics.
5. Social science methodologies.

Outcomes may include or may have included both positive and negative elements, for example:

1. Increased interest in certain specific research questions.
2. Decreased amount of time spent in personal pursuits or with family as a result of increased time spent doing research.

General outcomes may include or may have included:

1. Progress in the field of astrobiology.
2. Progress in the field of artificial life and computational intelligence or related fields.
3. More effective teaching of astrobiological and computer science concepts.
4. Beneficial policy making based on an increased awareness of ethical frameworks and their application in society.

Specific Outcomes of the Research

Several innovations are introduced in this paper. First, the results of the exploratory framework include the identification of five different types of ethical perspectives depending on their focus: personal, social, cultural, environmental, and quantitative. This observation is distinct from traditional scholarship that has looked at deontology and consequentialism as two poles of ethical structure.

Second, during the process of analyzing language-based data to attribute them to different perspectives, it became apparent that similar techniques are employed in psychometric analyses increasingly used in conjunction with social media, both for sales and to influence election campaigns, and that these techniques are associated with heightened polarization and social fragmentation. The work of highlighting differences in ethical perspectives to promote greater social harmony and integrated decision-making to address the needs of diverse stakeholders via awareness can be seen as a prescriptive to counter the kinds of fragmentary applications as described above. Thus the project presents an alternative use of these kinds of data that is timely.

Third, the analysis presented concludes with the observation that astrobiologists and computer scientists are on parallel but different trajectories with regards to ethics. Information technology, which includes computer science, has tended to produce exploratory (and speculative) ethical perspectives in advance of the technological innovations themselves. In contrast, robust ethical systems treating other kinds of technologies may develop only decades or centuries after the technologies themselves are introduced.

Fourth, several specific recommendations were developed during the process of the analysis, and some of these are novel, for example (a) allowing the users of autonomous vehicles the choice of deciding optimal valuation of pedestrian versus passenger safety in cases of danger where all other things are equal; (b) treating genomic information as a potential future trade good with extraterrestrial civilizations, such that preserving biodiversity can be seen as having a utilitarian benefit; and (c) treating the creation of machine life as including parental obligations.

Finally, a "Recommendations for Policy-Makers" hand-out and two lesson plans were developed that can be used by the public. In general, the project also serves as an example of this type of exploratory, qualitative research and how it can produce useful results.

Background and Role of the Researcher

The author is an artist and language teacher who became interested in finishing earlier studies in geology, and in the process became a mad scientist. He is currently running a set of experiments to make solar panels out of ice for use in cold climates, and also works on artificial ice creation to protect the ice caps. When he is not doing science work, he runs a 501(c)(3) non-profit organization which he set up to help independent scientists. He continues to make art and recently wrote a play about Hypatia of Alexandria (currently in production). His main love, however, is teaching, and his classrooms are dynamic and student-centered. At the time of this project, he is a doctoral student in sustainability education at Prescott College. His two most cited scientific works are "Catching lightning for alternative energy" and "Earth electricity: A review of mechanisms which cause telluric currents in the lithosphere."

The researcher took on the roles of: researcher, facilitator, teacher, consultant, and author.

Definition of Terms

A glossary is included as Appendix A. More detailed explanations of terms are included in this section for interest and clarity. *Mathematics* is taken as the study of mental objects with reproducible properties. This contrasts with *personal* or *religious* beliefs, which are seen as mental objects that do not have reproducible properties. *Science* is taken as a framework for investigating phenomena that have observable properties (Borovik, 2009; Davis & Hersh, 1981). The distinctions here are meant to generate a high level of respect for peoples' personal views.

Constructivism is the belief that people construct their own knowledge set within a social context, and that the role of a teacher or therapist is facilitative (Bruner, 1985). It is a person-centered viewpoint that promotes open-ended questioning and processes whose outcomes emerge from the process itself.

Ethical perspectives that rely on people's internal sense of duty or character include Kant's categorical imperative—to act in a manner that one's actions might be taken as the best possible in every consideration as a matter of duty. Ethics based on duty are *deontological* (Carmichael, 1949), and this term shares the common Greek root *dei-* with *duty*, signifying necessity. The idea behind deontology is that there exist inherent features of situations that of themselves require a person to act. A deontological system of ethics is built upon the work of discovering and describing these features. In this paper, this and related ethical perspectives will instead be termed *role-based ethics* as a more

accessible usage and also to emphasize—instead of duty—the internalized social aspect of this type of ethical perspective.

Deontology will be contrasted with an ethical framework that explores the outcomes of actions, termed *consequentialism*. The idea behind consequentialism is that there exist outcomes of actions that may be measured, compared, and optimized. A consequentialist system of ethics is built upon the work of discovering and describing these outcomes. Two consequentialist perspectives will be described in this project. *Utilitarianism* promotes the greatest good (or least bad) for the greatest number by comparing outcomes. *Pragmatism* promotes novel organization and technology based on re-evaluating data to look only at the effects of things.

In simple terms, the contrast taken up in this dissertation is between an internal (deontological) and external (consequentialist) ethical framework. Both are explored, and new results are added to each. They are seen as complementary, as are different ethical perspectives within these frameworks.

Limitations and Delimitations

There are various limitations to this study:

1. As it is a qualitative study, data are not representative of a larger body of researchers nor of the same researchers at a different time and place.
2. As data analysis employed inductive reasoning, tests for validity (namely, that results from several inductive processes should converge, and that there be internal consistency) addressed hypothetical rather than theoretical soundness.
3. Bias on the part of the researcher is inevitable.

There are various delimitations to the study:

1. Study participants will have had distinct constraints on their time, and thus in-person data collection was ruled out.
2. Data were not analyzed by different researchers.
3. Lesson plans were not tested for efficacy.
4. Policy recommendations were not tested for efficacy.

The delimitations can be taken up by the research community if the study proves intriguing.

Summary

The importance of recognizing opportunities for transdisciplinarity was highlighted in the first section. Specifically, astrobiologists and a subset of computer scientists are working with similar processes or patterns (evolution) and similar topics (extraterrestrial or artificial life). The overlap suggests that increasing opportunities for researchers to share their ideas would be useful. The implications of such profound progress, if it were to be realized, suggest ethics as an important and timely area of study related to these fields of research. Subsequent sections specified and delimited the research design of data gathering (questionnaire and Skype discussions), analysis (qualitative using inductive reasoning within a constructivist framework), and products (lesson plans, policy recommendations, and this report of the results). Further, conceptual frameworks (scientific, constructivist, ethical) were defined. Limitations to the study (e.g., those specific to qualitative research) and delimitations (i.e., no in-person data collection, no research validations by different researchers, and no efficacy testing of the research products) were also specified.

CHAPTER II: METHODS

Civilization can be seen as a balancing act between respect for nature, on the one hand, and a desire to accumulate material goods, on the other (cf. Thoreau, 1854/1971). Thus, a discussion about the rights of living organisms is not new, whether focused on the rights of ecosystems (Kosoy & Corbera, 2010) or of subjugated peoples (Kinley & Tadaki, 2004), animals (Donaldson & Kymlicka, 2011), or other organisms. Expanding rights is an obvious subtext of civilization.

Novel organisms are now being constructed with genetic engineering techniques, and discussion has focused on safety and perceived benefits more than on ethics and rights (cf. Uzogara, 2000). Self-reflection has stalled: vast informal experiments with genetically-modified organisms are currently taking place *in situ* throughout much of the planet as regulation has been ignored, or poorly designed, or not deemed necessary. This is not the end of the new-organism story. Astrobiology may be successful in finding novel living organisms. Computer science may be successful in creating novel living machines—as there are already people using brain-computer interfaces to control lost limbs (Rossini et al., 2010), that is, there are already cyborgs among us. Of course this is a good development for amputees! Clearly, a constructivist approach—wherein respect for the power of people to create their own life stories, knowledge, and outlooks—is called for since both positive and negative outcomes can be imagined and lobbied for.

Overview of Purpose and Research Questions

The following objectives suggest themselves:

1. To explore the ethical strategies that members of the astrobiology and artificial life and computational intelligence communities deem useful in promoting progress in their fields.
2. To raise awareness across these academic communities of the work and ideas of their peers as it relates to ethical considerations for living organisms found off-planet or created.
3. To provide additional tools for teaching astrobiology and computer science and thereby raise literacy in the subject.
4. To provide information and recommendations that will help policy-makers understand ethical considerations related to living organisms.

The research questions of this study rest upon these objectives:

1. What are ethical considerations that astrobiologists hold about their work?
2. What are ethical considerations that computer scientists involved in artificial life or computational intelligence hold about their work?
3. What examples of lesson plans might be developed to teach aspects of astrobiology or computer science related to insights gathered from the ideas expressed by astrobiologists and computer scientists, respectively?
4. What policy recommendations in the realm of ethics can be made related to the emerging work of astrobiologists and computer scientists involved in artificial life or computational intelligence?

Methods

For data collection:

1. The research project solicited responses to an electronic questionnaire sent out to astrobiologists and computer scientists working in artificial life or computational intelligence. Analysis took the form of an emergent process in order to gain information and insight from the text of the answers.
2. Questionnaire respondents were given an opportunity to participate in a Skype discussion focus group to further communication related to emerging ideas and crossover between the two fields. Analysis and synthesis took the form of an emergent process to gain insight and inspiration for promoting progress in each field.

For communication:

1. Respondents were given the option of seeing their and other respondents' survey answers after their last prompt, and also via email before the analysis began.
2. Results from the analysis of the data are presented in this dissertation and a draft has been made available to respondents; the dissertation itself will be made freely available online.
3. Lesson plans related to the subject are included in the dissertation.
4. Recommendations for policy makers are included in the dissertation.
5. A short book version of the study suitable for the public is being planned.

Sample

Potential respondents were identified with three methods:

1. Those whom the survey author had met at conferences.

2. Those whose prominence in the field is well-known as indicated in field-specific literature.
3. Those found by using a search of websites with specified keywords.

Members of the first group were considered more likely to participate since there was a social connection with the author. Members of the second group were considered more likely to have important perspectives since their work is highly cited or otherwise influential. Members of the third group were considered potentially able to provide additional insights. Thus, the participant selection process was meant to be optimized for perspective richness. Special efforts were made to recruit women and representatives from racial and ethnic minority groups as a means of adding to this richness, and this recruitment was a part of category (3) search of the internet using keywords.

The inclusion criteria for the three groups were as follows:

1. Academics who attended conferences in astrobiology or computer science that the author also attended:
 - 11.2015: “Re-conceptualizing the Origin of Life.” Carnegie Institution for Science.
 - 1.2016: “Early Earth, Venus & Mars: Three Experiments in Biological Origins.” Earth-Life Science Institute, Tokyo Institute of Technology.
 - 1.2016: Gordon Research Seminar. “Understanding Life's Origin by Diving Outside of the Pool.” Galveston, TX.
 - 1.2016: Gordon Research Conference. “Bridging Disciplinary Perspectives to See Further Into Life's Origins.” Galveston, TX.

- 2.2016: Australasian Conference on Artificial Life and Computational Intelligence (ACALCI). Canberra, Australia.
2. Academics who are prominent in the literature in astrobiology or computer science, such that a paper authored or co-authored by them appears in the first several pages of a Google Scholar search, by using a protocol to ensure faithful coverage of the field (including search terms that overlap) and counterbalance any failings of the search engine (scholar.google.com, 2016), typically the first 25 articles, though for origin of life—40—since many papers are old and authors deceased; and for machine learning—50—since many papers past the first 25 have a thousand citations or more, with the following as search terms: astrobiology, origin of life, exobiology, synthetic biology, artificial life, multi agent system, robotics, machine learning, computational intelligence, artificial intelligence, evolutionary algorithms, genetic algorithm, brain computer interface, machine consciousness, metalearning, natural language processing, computational linguistics, or affective computing.
 3. Academics or researchers in astrobiology or computer science whose information is captured in the first several pages of a Google search (www.google.com, 2016), typically the first 50 webpages, though for astrobiology women, “origin of life” women, exobiology women, synthetic biology women, and “machine learning” women—10—since there are so many relevant results listed, when adding each of the preceding search terms to each of the following search terms: women, diversity, ethnic, minority, disability.

The exclusion criteria for the three groups were as follows:

1. Conference attendees whose contact information was not available electronically.
2. Authors whose contact information was not available electronically.
3. Some academics or researchers who were looking for early career jobs (e.g., post-doctoral fellowship positions) when the search term produces results with more than 100 in a category, that is, in the search: astrobiology women; and some who are clearly focused only on business or some other field (and not research) pursuits, that is, in the search: “multi agent system” women, robotics women; plus some when a single website lists more than 100, and then 40 are chosen using a random number generator tuned in to atmospheric noise for its randomness (random.org, 2016), that is, in the search: “machine learning” women, “computational intelligence” women; and also some whose contact information was not available electronically.

Note that there are also exclusion criteria that are self-imposed, i.e., respondents opt to exclude themselves.

The number of potential respondents was approximately 1555: 620 from astrobiology and 935 from computer sciences. While the number of astrobiology contacts was only about 2/3 as many as computer science contacts, those in computer science were mostly unknown to the author (i.e., only 35 conference contacts) whereas for astrobiology many more were known (i.e., about 260 conference contacts). The aim was about 150 participants in the questionnaire and about 15 participants in the Skype group discussions, with equal numbers from the astrobiology and computer science fields.

Data Collection Protocols and Procedures

The project was accessed via the internet and participants came from wherever internet access was possible. Questionnaire responses were textual and included names and institutional affiliations if respondents wished, but not demographic information. Email was sent out, subject to minor modifications in language that did not change the meaning but which were necessary, for example, to include the name of the conference where the author had met the potential participant. Likewise, the words “We met during XXX” was not included except for prospects whom I met during one of the conferences I attended. The contact letter is presented in Appendix B, as are the information sheet, FAQ list, and consent form that respondents were presented with as they started to take the questionnaire. The questionnaire itself is in Appendix C.

For participants in the Skype group discussion, consent to participate was implicit in the communications that were undertaken to arrange the logistics for the group, namely, people consented to join by sending an email stating that they wished to join. The author had planned to record and transcribe the discussions, but this plan fell through. Oral consent was the planned mode of obtaining consent, chosen for its flexibility and responsiveness to participant needs. One participant stated beforehand that she would be less candid in her answers if she were being recorded. Thus, the decision was made not to record the Skype group discussion. However, this participant was not able to join the group discussion because of a technical fault. In the meantime two participants had already joined and were in the midst of productive communication. The decision was made to record and seek consent afterwards, with one participant accepting and the other stating that they would have answered differently had they known of the recording. This

participant was willing to allow for the use of the recording and a transcription if also given a chance to review and make changes to the analysis. The decision was then made to delete the recording without transcribing it, following the idea that if the original consent discussion had taken place beforehand as planned, the author would have chosen not to record. The author subscribes to a policy that if a participant indicates that they would be careful with what they say if recorded, then the researcher opts for no recording in order to favor candor. The recording was deleted without ever having been viewed. Moreover, the author suggests that oral consent in a group setting should be avoided if at all possible to prevent this type of issue. The process led to a breach of faith that could have been avoided.

The Skype group discussion began with small talk as people joined the discussion. A one-on-one Skype discussion occurred four hours before the main discussion as a participant had incorrectly calculated the time zone offset for the call. This allowed the researcher and participant an opportunity to communicate fruitfully, and the opportunity was not wasted. A short one-on-one Skype discussion also occurred with another participant as well before the main group discussion. Potential questions were prepared beforehand to help guide the group discussions, and these had been emailed to participants for interest. They are located in Appendix C.

Regarding data use: Data do not include demographic nor contact information and will be housed as a document or documents online and may be kept indefinitely, to further the academic community's work in exploring ways to promote progress in astrobiology and computer science. The original data will be housed on a personal computer that only the author has access to.

Regarding privacy, consent, and protection for vulnerable populations: The study asks people to consider their current research. The study also asks people to consider questions related to definitions for life, living organisms, living systems and ethical frameworks. The study is conducted via online questionnaire and Skype group discussion. In each of these settings there is contact information for the lead researcher and the ability to provide feedback. If a person were to be distressed by participating, however unlikely, they would hopefully stop. They might also post a comment in the discussion or provide feedback in the questionnaire. The researcher will stay attuned to any comments and will strive to address these in a humanistic framework. The researcher does peer counseling with the mentally ill and has developed a suite of therapy skills. Anything outside the researcher's expertise will be addressed by offering referral and following up out of concern, if necessary. In the event that a respondent or respondents request it for any reason, their data will be deleted.

Data Analysis and Procedures

The data, which consist of strings of text from the questionnaire and impressions from the Skype group discussions, were analyzed via an emergent strategy that included iterative processes to look for themes and develop these. Results are described in Chapter IV: Data and Analysis.

Critical Reflection on the Research Design

The project was designed to be exploratory, and the results produced are a reflection of how open-ended the analytical processes are. First, the literature review section was undertaken not as an encyclopedic objective, but rather as a reflective exercise to explore how extant academic literature could provide a new system of looking

at complementary ethical perspectives, and this goal was met with success. The case studies and framework of complementary ethical perspectives are useful prototypes for exploring different values at the same time.

Second, the questionnaire data include dozens of answers that are inspiring and useful for teaching, especially for helping students see that the paths to successful careers are often circuitous and malleable. The quality of the answers will allow for their use in a book for the public. These favorable outcomes are a result of the study design, wherein the questions were devised to allow respondents to reflect on their own ideas about their careers and how ethics may play a role.

Third, these data and the information gathered during the group discussions, plus a strong discussion during the dissertation defense gave the author a chance to reflect deeply on both astrobiology and computer science, and the observations based on these data resulted in novel recommendations and insight into the differences between how ethics for each may develop. These observations have been personally useful in developing a new research focus.

The research was not designed to produce strong quantitative data, and the questionnaire did not collect any demographic information. As a result, more definitive answers related to differences in perspective between and among astrobiologists and computer scientists were not possible. To undertake a statistical analysis would have required testing the questionnaire as a survey instrument and normalizing results with parameters that would look at how language is used in the questions and answers over a very large number of respondents in various cultures and settings, and even then there is a strong question about the validity of language-based analysis itself in predicting beliefs

and attitudes. Thus the type of exploratory research that was undertaken—generating impressions via multiple reflections—can be seen as an optimal use of resources in generating novel research ideas and preliminary observations without misrepresenting the data. Yet, by nature, these results are preliminary.

Also, it would have been useful to have had a greater number of respondents, more time to produce the analyses, more time to design the recommendations for policy makers and to include eye-catching graphical elements, and a chance to test the lesson plans in several classrooms. Thus, the utility of the present study is limited by the research design and will appeal to a smaller audience of readers than research projects that command more resources to work with. It is hoped that nonetheless the ideas presented herein will be a source of insight.

Summary

The rationale for using a constructivist methodology was presented in the introduction to this chapter as rising from the potential conflicts of various stakeholders. Research objectives were given based on professional and contextual parameters. An electronic questionnaire and Skype group discussion were described as data collection methods that will work for (busy) study participants. Sampling techniques were devised to ensure that a wide range of expert participants, plus those who are members of vulnerable populations, were included in the study. A consent form, information sheet, questionnaire text, and list of Skype group discussion questions were presented. Analytical techniques were emergent and are presented in the data and analysis chapter. Communicative strategies were offered that will allow for public access. Public data access after the study was suggested in the form of a book.

CHAPTER III: LITERATURE REVIEW

In the etymology of *ethics* is the Greek term *ethikos*, which can be found in the title to Aristotle's work *Nichomachean Ethics* and other ancient academic texts (Minnameier, 2005). It refers to morality, but not simply how one may act—but rather an attempt to formulate theory or science of morality. It is derived from the Greek term *ethos* which refers to a spirit, as in *the spirit of an age*. In less poetic terms, one may think of *ethos* as a mood that helps to define something. Ethics are personal, even if there is to be a systematic philosophy of them.

The following two paragraphs introduce a connection between independence, respect, and ethics—with a paradigm based on parenting. Healthy two-year-olds in their behavior are pointed in their assertions. They know what they want. As a parent, the work of negotiating with a child has begun (Crockenberg and Litman, 1990). Children of this age can be reasoned with—or distracted with some better (and more inspiring) object of desire if the aim of the parent is to secure an outcome different from that of their child—in a manner that is respectful. Effective parenting is based on the relationship that forms from these types of interactions (Hoeve et al., 2009).

At adolescence, challenges to personal health that arise are made more difficult by poor parental relationships and communication: (a) it is much easier to practice respecting children's choices while they are young than after adolescence—as the dangers being faced by children are often more constrained than those faced by adolescents. (b) It is much harder both for parent and adolescent to have the adolescent's actions only at majority be seen as independent—precluding a positive track record of trust. There ought to have been this connection in place already (Johnson et al., 2002). Respectful action as

an adult is closely tied to respectful treatment and independence as a child. Thus *respect* and *independence* are each seen as essential for human development and behavior—and ethics.

Just as each household has its own parenting style, so too each culture has its own ethics—its own spirit. Ethical perspectives are in fact more numerous than cultural systems, with several competing at times. There are thousands of human cultures still extant. See Table 1 for a list of cultures found in the Human Relations Area Files (HRAF) housed at Yale University, for example (HRAF, 2016). The files are part of an international organization of scholars with more than 300 members; documents are thematically coded by paragraph to aid in research. Even so, the cultures listed are obviously only a small fraction of cultural groups. Another example: *Ethnologue* publishes statistics about the approximately 7,500 known languages in the world (Ethnologue, 2016), and major language families—comprising at least 1% of the world's known languages—are listed in Table 2. Languages can define an ethical perspective strongly—as can culture. Philosophy, asserted Heidegger, grows upon the substrate of language (Heidegger, 1959/1971). There are: (a) many cultures in the world, (b) many languages in the world, and thus (c) many ethical perspectives in the world.

At this point it is possible to make three inferences, based on the large number of cultures and languages in the world: (a) there are many different ethical perspectives in the world, as described in the paragraph above; (b) a professional respect for cultural differences is used in any exploration of ethics across cultures, and (c) attempts to construct a universal system of human ethics are tentative (as any construction based on a large number of elements cannot help but be tentative until all elements are checked). The

Table 1

List of Cultural Groups Found in The Human Relations Area Files at Yale University

Region	Cultural Groups in the Human Relations Area Files
Africa	Akan, Amhara, Azande, Bagisu, Bambara, Banyoro, Bemba, Bena, Betsileo, Dogon, Ganda, Gusii, Hausa, Igbo, Kanuri, Kpelle, Lakeshore Tonga, Libyan Bedouin, Lozi, Maasai, Mbuti, Mossi, Nuer, Ovimbundu, Rwandans, San, Shluh, Somali, Tanala, Tiv, Wolof, Yoruba, Zulu
Middle East	Basseri, Bedouin, Iran, Israelis, Kurds, Lur, Palestinians, Rwala Bedouin, Turks, Yemenis
Europe	Basques, Bosnian Muslims, Croats, Early Icelanders, Greeks, Highland Scots, Icelanders, Imperial Romans, Montenegrins, Saami, Serbs, Slovenes
Asia	Ainu, Alorese, Andamans, Badaga, Baluchi, Bengali, Burusho, Central Thai, Chukchee, Garo, Ghorbat, Hazara, Iban, Ifugao, Inner Mongolia, Karakalpak, Khasi, Korea, Koryaks, Kyrgyz, Lepcha, Mentawaians, Miao, Mongolia, Monguor, Okinawa, Pamir Peoples, Pashtun, Rungus Dusan, Santal, Semang, Sherpa, Sinhalese, Taiwan Hokkien, Tajik, Tamil, Turkmens, Uzbeks, Vedda, Vietnamese, Yakut
Oceania	Aranda, Chuuk, Eastern Toraja, Hawaiians, Kapauku, Lau Fijians, Malekula, Manus, Maori, Orokaiva, Samoans, Santa Cruz, Southern Toraja, Tikopia, Tiwi, Tongans, Trobriands, Ulithi, Woleai Region, Yapese
North America	Aleut, Alutiiq, Amish, Arab Americans, Arab Canadians, Assiniboine, Basque Americans, Blackfoot, Cajuns, Cherokee, Chicano, Chinese Americans, Chinese Canadians, Comanche, Chipewyan, Copper Inuit, Creek, Cuban Americans, Delaware, Haitian Americans, Hopi, Innu, Iroquois, Italian Americans, Italian Canadians, Jews / Hasidim, Klamath, Korean Americans, Lower Chinookans, Navajo, North American Armenians, North American Hmong, Ojibwa, Pawnee, Pomo, Puerto Ricans, Quinault, Sea Islanders, Seminole, Serbian Americans, Stoney, Tlingit, Ute, Western Apache, Western Woods Cree, Yokuts, Yuki, Zia Pueblo
Middle America and Caribbean	Cubans, Dominicans, Garifuna, Huichol, Island Carib, Jamaicans, Kuna, Maya (Yucatán), Tarahumara, Tzeltal, Zapotec
South America	Aymara, Bacairi, Bahia Brazilians, Barama River Carib, Bororo, Guaraní, Inka, Jivaro, Kogi, Mapuche, Mataco, Mundurucu, Ndyuka, Ona, Saramaka, Shipibo, Tehuelche, Siriono, Tukano, Tupinamba, Warao, Yahgan, Yanoama

Table 2

Language Families Comprising at Least 1% of the World's Known Languages

Language Family	Languages Spoken	Percent of Total
Niger–Congo	1,538	20.6
Austronesian	1,257	16.8
Trans-New Guinea	480	6.4
Sino-Tibetan	457	6.1
Indo-European	444	5.9
Australian	378	5.1
Afro-Asiatic	375	5.0
Nilo-Saharan	205	2.7
Oto-Manguean	177	2.4
Austroasiatic	169	2.3
Volta Congo	108	1.5
Tai-Kadai	95	1.3
Dravidian	85	1.1
Tupian	76	1.0

present subject of study is thus likely to be relevant to the general study of comparative ethics in some capacity. The field is not tapped out. From here we move to a brief examination of differences between morality, law, and ethics before returning to the subject of comparing ethical perspectives. The very large number of extant cultures (see Tables 1 and 2) becomes important in defining the validity of the ethical perspectives chosen later in the chapter for analysis.

The difference between morals and morality is one of scale: *morals* refer to customs and behaviors; *morality* refers to the spirit behind a set of customs and behaviors, that is, morality is synonymous with ethics. Moving from the personal to the social scale involves abstraction—as scale invariance implies that there be an underlying structure. In historically-codified rules for behavior—one class of these rules is simply

Table 3

Three Bases of Legal Systems

Legal Basis	Description	Example
Common Law	Judges decide cases and their decisions may set precedents, i.e., the final arbiter of the law is judges.	The legal system of the US is based on British common law.
Civil Law	The legal code is created by some entity (e.g., a parliament, monarch, etc.) and judges interpret the law but their decisions do not set precedents.	The legal system of Denmark is based on Scandinavian and German civil code.
Religious Law	A religious text is seen as definitive, and religious leaders interpret the law.	The legal system in Saudi Arabia is based on Islamic religious law.

law. A comparative basis of legal systems is given in Table 3. Some combination of the three bases listed forms the legal systems of countries.

To explore the application of law: human civilization is becoming less violent if one looks through a very coarse lens (Campbell, 2014; Pinker, 2011). Cannibalism of enemies is now only rarely practiced, thus one source of violence in civilization is gone. Likewise, from antiquity to early modernity it was much more common to suffer slavery as a consequence of war or by being a child sold into it (Fynn-Paul, 2009). Conscription is now less common (Gabriel, 2002). In short, much of the world now lives under stable legal systems, thus the prevalence of personal violence is less than previously. More people know what to expect of their day. This has arguably been a deliberate progression: The rule of hospitality of the ancient Greeks and the codification of Roman Law each aimed to produce this result out of deference to a vision of future stability (van Wees, 2016). The teachings of the Buddha were a response to the growing power of nation-states and were delivered in the vernacular (Hanh, 1987; Thapar, 1990). Whether this change is monotonic is not clear, and perhaps this coarse lens is not getting the bigger

picture accurately—especially if one considers difficulties of quantification over millenia (Willigan & Lynch, 1982). Notwithstanding, this is a supposition: human civilization is becoming less violent towards humanity as a consequence of the application of law.

To go further along this theme: ethics encompass a larger scope of behavioral recommendations than laws. For laws based on all three systems in Table 3, it is possible to assess whether that law is ethical or not. Their content can be held to a higher standard. This makes sense, as the spirit of something is an abstraction of a thing and not the thing itself.

To go yet further, let us consider for the next several paragraphs the history of science, and as entry let us consider a few examples of unethical things, and empire. What follows first is a brief example to illustrate conflict of interest—which itself implies that personal morals are malleable and arise from personal concerns. When a researcher submits a paper for peer-review, for example, they typically disclose any financial or personal ties they may have that could influence how they view their research. From this it might be inferred that ethics could spring from (or be influenced by) the source of a person's livelihood. Thus, a clear valuation may be challenging. The socio-economic context of an action or thing influences its role.

Literacy itself has been historically a tool of empire (Innis, 2007). Ancient Egypt amassed granaries and tallied them within a temple system wherein literacy and learning, for example, were central to authoritarian processes (Hudson & Wunsch, 2004). The British Empire, millenia later, also relied on an extensive system of written communication to administer colonies in great detail (Bayly, 1996). The remains are still extant: the author of this dissertation has visited the Writers' Building in Kolkata, India,

the seat of all record-keeping and official communications, where the work of the clerks maintained the colony for the East India Company (Bose, 2012). Things are not so black and white: the poetry of Charles Lamb (1797/1909) is beautiful, and yet he was employed as a writer for that company responsible for immense destruction (Robins, 2012). Thus one sees a contradiction. Here is the opening stanza of Lamb's "A Vision of Repentance" to confirm the author's assessment of the beauty therein:

I saw a famous fountain, in my dream,
Where shady path-ways to a valley led;
A weeping willow lay upon that stream,
And all around the fountain brink were spread
Wide branching trees, with dark green leaf rich clad,
Forming a doubtful twilight—desolate and sad. (Lamb, 1797/1909).

The above text's narrative is unrelated to the setting of this essay, yet the beauty is unmistakable and exemplifies the conflict in both contexts. The same writing hand helped further immense, widespread and systematic human rights abuses in India. There is a struggle to make sense of this, to be sure. Lamb wrote in an age of colony as well as poetry—during the development of science (Elliot, 2010). The path to modern scientific perspectives sprang from this conflict of the heart (Nickles, 1994), and a need for personal liberty (Bronowski, 1956)—to see clearly the context of this suffering (Gabay, 2004)—led to science (Riskin, 2002). Seventy-five years earlier Newton had written the following:

In experimental philosophy we are to look upon propositions inferred by general induction from phenomena as accurately or very nearly true, notwithstanding any contrary hypothesis that may be imagined, till such time as other phenomena occur, by which they may either be made more accurate, or liable to exceptions. (Newton, 1687/1726/1846, Rules of Reasoning, Rule 4).

Science can from this be seen as a clear system for analysis, one that includes: experiment, induction, and falsification. Science gives its practitioner applied contextual tools. The burden of proof is on a person's skills, reasoning, faculties, and sources of data. The front of Newton's book echoes this sentiment. The poem composed for the front matter was written by Newton's friend and colleague Edmond Halley, who encouraged and funded the publication, and created the woodcuts of the diagrams as well:

Sing him, ye Muses, for Right can approve,
No Mortal nearer touch the Gods above. (Halley, 1687)

A methodology in Newton's volume was presented to lead people from the bonds of superstitious law—to free their minds and actions for direct apprehension of nature and spirit. Hence the mention of Gods and secrets revealed in Halley's poem forms a theme for the age of new skills, one of growing enlightenment. Though it is not clear by what scale that freedom may be measured, the centrality of freedom to modes of thought and analysis was a central concern (Kant, 1784).

To sum up to this point, for clarity, the current topic is ethics and how ethics have interacted with the development of science. This dissertation has touched upon the following points so far:

- Ethics are based on the spirit (or mood)—the abstraction of a thing. (p. 35).
- Respect and independence are related to ethics via human development. (pp. 35–36).
- Ethical perspectives are embedded in culture. (p. 36).
- There are a wide variety of languages and cultures in the world. (pp. 36–38).
- Ethics share some functionality with law. (pp. 39–40).

- Ethics are above law in their analytical power. (p. 40).
- People seem susceptible to unethical actions based on their economic context. (pp. 40–41).
- Science developed as a means of freeing a person through their own effort. (pp. 41–42).

The development of a scientific framework has continued from these underpinnings into the present. A modern mathematician, Alexandre Borovik, paraphrasing colleague David Mumford who borrowed the notion in Davis and Hersh (1981), explains the last premise above well in asserting that, in contrast to religion: “Mathematics is the study of mental objects with reproducible properties” (Borovik, 2009, p. 31). In addition to its elegance, this statement lays the framework for a system of thought that is deeply useful and allows for healthy critical distinctions.

First, consider the complement of mathematics, namely, mental objects without externally reproducible properties. Dreams, religion, and personal philosophy can be seen as studies of mental objects that are personal (or internal, that is, without externally reproducible properties). Likewise, science can be seen as a study of physical objects with observable properties (Borovik, 2009). See Table 4. All three realms are valid such that each framework is sufficient to define each area consistently. Some may object to the restriction of religion as an internal realm, yet atheism does not seem to lead to externally marked differences in a person, that is, one cannot tell a person's theistic beliefs or lack thereof based on external observation. Despite being able to observe, for example, a person wearing religious clothing or engaging in a religious practice such as crossing oneself before taking a specific action, these outward signs can be performed equally well

Table 4

Three Realms of Knowledge

Realm	Object Properties
Science	Physical objects with observable properties
Mathematics	Mental objects with reproducible properties
Philosophy, Religion, Dreams	Mental objects without externally reproducible properties

by both agnostic and believer, and make no distinction between the two regarding their internal beliefs. Thus the framework given in Table 4 is consistent with observation. The distinction between the three realms (science, math, and personal / religious philosophy) allows a person to apply different tests to each, that is, information in the religious realm springs from personal observations; information in the mathematical realm springs from observations of idealized forms that can be communicated in the language of math; and information in the scientific realm springs from external observations. In short, this type of framework allows a person the freedom of respecting other perspectives—of being capable of abstract thought.

To return briefly to history: Immanuel Kant was born in 1724, two (or three) years before the death of Isaac Newton. Kant revolutionized philosophy in Europe, creating a very clear structure based on terminology to account for observed phenomena (Kant, 1781). In the physical sciences Kant addressed some structural points, such as correctly ascribing the Milky Way's formation to a very large cloud of gas and dust (Kant, 1755). In moral philosophy Kant identified duty as a feature that allows people a foundation upon which to build morality (Kant, 1785). Attaching one's sense of duty to that which is larger, i.e., the categorical, leads to a moral role. The validity of one's actions is testable

—as if by them one is creating a universal law. Duty is not fulfilled without this attachment, this categorical imperative.

In contrast, utilitarianism explores the results of actions (Mill, 1859). The test is whether the material results of actions are for the greatest good (Bentham, 1780/1823/1879; Mill, 1861/1863). Jeremy Bentham coined the term utilitarianism during a time of colonialism and slavery—a period that includes loss of culture and genocide in many lands (Pitts, 2003). Because of the focus on results, this ethic is called currently *consequentialism*, that is, the consequences of actions are explored (Stocker, 1969). This contrasts with the ethic introduced by Kant, *deontology*, which explores the application of duty to a larger realm. Both are analytic, though the accounting for one is perhaps monetary (utilitarian), and for the other, personal (role-based).

For a summary of these two and other types of ethic, see Table 5. This section has introduced the topic of ethics and shown perhaps that an ethic introduces a method of analysis in addition to being an idea upon which people base their actions tacitly. In subsequent sections a method of analysis will be developed, and then applied to various cases that are recent (the first three) and future (the last two):

1. The hole in the ozone layer.
2. Genetically modified organisms.
3. Climate change.
4. The discovery of life on other planets.
5. The development of living machines.

These case studies will be by nature preliminary, and will be offered as an example of the type of analysis that is useful when complementary ethical perspectives are desired.

Method

There are two purposes in presenting the information in Table 5. The first is to familiarize the reader with a variety of ethical frameworks. The entries span more than three millenia and contain some samples, but it is not encyclopedic; there are no encyclopedias of ethics that are complete. The method itself of choosing what to include was an informal internet search and arbitrary: missing are any African ethical perspectives, for example, or any from South America, or from various countries or tribes, cultures, or language-based ethics. Inferences about the data in Table 5 should be taken as anecdotal. Notwithstanding, inferences are the second purpose in presenting the data. The fourth column contains metrics devised by the author for testing for the presence of this ethic. From the data in this column, a framework is developed for analyzing case studies.

Table 6 shows these metrics grouped thematically. Metrics assessed have been listed more simply in the third column, while the metrics themselves have been grouped into five categories for clarity in the first column: personal, sociological, cultural, ecological, and quantitative. The grouping was done inductively, namely, based on a thematic assessment of the focus of each. Other groupings are possible, and whatever inferences follow from this particular grouping should be taken as preliminary only.

Notwithstanding the obvious incompleteness of Table 5 upon which Table 6 is based, and the inductive nature of the division of categories in the first column of Table 6, it seems a worthwhile endeavor to identify at least one metric from each category that could be seen as representative of that category for ethical considerations. There is one additional quality that was used in the selection process: whether the metric appeared to

Table 5

List of Selected Ethical Perspectives, Including Those of Selected World Religions

Name	Origin or Early Principal Proponent	Focus	Metric
Hinduism	Vedic Period, around 15 th century BCE, India and Nepal	<ul style="list-style-type: none"> • Eternal duties, such as honesty, refraining from injuring living beings, patience, forbearance, self-restraint, and compassion. • Cause and effect linked to rebirth. • Society divided into classes. • Numerous paths to enlightenment. • Abundant rituals. • Authority of religious texts. 	<ul style="list-style-type: none"> • Blissful self-awareness is developed. • Social order is maintained. • Sacred rituals are performed well according to adherents.
Judaism	13 th century BCE, Israel	<ul style="list-style-type: none"> • The community is based on an historical relationship with a deity. • Good deeds support society. • Sacred texts are open to interpretation to further community well-being. • Rituals and festivals are emphasized. 	<ul style="list-style-type: none"> • Outcomes promote community well-being and life. • New interpretations or stories have arisen. • Sacred rituals are performed well according to adherents.
Zoroastrianism	10 th century BCE, Persia	<ul style="list-style-type: none"> • Free will is coupled with cause and effect. • Good thoughts, words, and deeds lead to renewal of the world. • Ritual purification involves fire and water, not animal sacrifice. 	<ul style="list-style-type: none"> • Evidence of good thoughts, words, and deeds exist. • Sacred rituals are performed well according to adherents.
Jainism	9 th century BCE, India	<ul style="list-style-type: none"> • The function of souls is to help one another. • Non-violence, pluralism, and generosity are central tenets. • Inner passions may be conquered through practices, rituals, and study. 	<ul style="list-style-type: none"> • Indications of non-violence, pluralism, and generosity are present. • Sacred rituals are performed well according to adherents.
Buddhism	Buddha, 6 th century BCE, Lumbini	<ul style="list-style-type: none"> • Suffering has a beginning and an end. • Practices (meditation) lead to an end of suffering. • Devotional practices (chanting, ritual) support the community. 	<ul style="list-style-type: none"> • Suffering is minimized in transitions.
Confucianism	Kongzi (Confucius), 6 th	<ul style="list-style-type: none"> • Family and social harmony are sacred. 	<ul style="list-style-type: none"> • Social harmony is maintained.

Name	Origin or Early Principal Proponent	Focus	Metric
	century BCE, Qufu	<ul style="list-style-type: none"> Humans are good and teachable through moral cultivation. 	<ul style="list-style-type: none"> Individual virtue increases.
Taoism	4 th century BCE, China	<ul style="list-style-type: none"> Emphasis on effortless action, simplicity, and nature instead of social order. Rituals and practices incorporate folk traditions and shamanism to bring transformation. Sacred texts and deities are worshipped. 	<ul style="list-style-type: none"> Transformations occur easily. Compassion, moderation and humility are cultivated. Sacred rituals are performed well according to adherents.
Hedonism	Aristippus, 4 th century BCE, Cyrene	<ul style="list-style-type: none"> Pleasure is the highest good. Knowledge is from objects of the senses thus not on a firm ground. 	<ul style="list-style-type: none"> Pleasure and delight are abundant.
Stoicism	Zeno, 3 rd century BCE, Athens	<ul style="list-style-type: none"> Self-control. Clear judgement. Inner calm. Contemplative philosophical practice. Virtue consists of a will that is in agreement with nature. Virtue is sufficient for happiness. 	<ul style="list-style-type: none"> Behaviors are in accord with a natural order. Emotions are measured and joyful.
Christianity	Jesus, 1 st century, Israel and Greece	<ul style="list-style-type: none"> Beliefs about the status of Jesus lead to salvation. Generosity is emphasized. There is an afterlife based on actions or faith. 	<ul style="list-style-type: none"> Evidence of generosity is present. An expression of belief is present.
Islam	Mohammad, 7 th century, Mecca and Medina	<ul style="list-style-type: none"> Veneration of the words and life of Mohammad as Divine revelation. Adherence on sacred routines for well-being. Charity is given to the community. There is an afterlife based on actions. 	<ul style="list-style-type: none"> Evidence that the community is cared for (charity) is present. Prayer is present.
Shinto	8 th century, Japan	<ul style="list-style-type: none"> Spirits of nature exist in the world. Rituals and the arts lead to purification. 	<ul style="list-style-type: none"> Harmony and good fortune are abundant.
Consequentialism / Utilitarian Ethics	Machiavelli, 1512, Florence	<ul style="list-style-type: none"> The consequences of actions are the basis for any moral assessment of them. 	<ul style="list-style-type: none"> Outcomes are rated to show their comparative good.

Name	Origin or Early Principal Proponent	Focus	Metric
Deontology / Kantian Ethics	Immanuel Kant, 1785, Königsberg	<ul style="list-style-type: none"> Ethical system based on duty. Categorical imperative to act as if making a universal law. 	<ul style="list-style-type: none"> Actions are guided by universally applicable notions.
Pragmatism	Charles Sanders Pierce, 1870, United States	<ul style="list-style-type: none"> The purpose of the mind is to do things. Ideas ought to be tested in practice. 	<ul style="list-style-type: none"> New methods have been tested.
Evolutionary Ethic	Charles Darwin, 1871, England	<ul style="list-style-type: none"> Considers the role of ecological processes in shaping ethical behavior. 	<ul style="list-style-type: none"> A body of work exists showing an evolutionary pathway for an ethical feature of interest.
Ethical Egoism	Henry Sidgewick, 1874, Yorkshire	<ul style="list-style-type: none"> People ought to do what is in their own self interest—since they know their interests best. 	<ul style="list-style-type: none"> Evidence for people acting in their own self interest exists.
Collectivism	Socialist theorists, 19 th century, Europe	<ul style="list-style-type: none"> Group interests are emphasized. 	<ul style="list-style-type: none"> Group interests are improved at the expense of individual interests.
Social Darwinism	Economic theorists, 19 th century, Europe	<ul style="list-style-type: none"> Policies reward the most competitive. 	<ul style="list-style-type: none"> The most competitive have been rewarded.
Egalitarianism	Political theorists, 19 th century, Europe	<ul style="list-style-type: none"> Equality for all people is emphasized. 	<ul style="list-style-type: none"> Evidence of equality is present.
Land Ethic	Aldo Leopold, 20 th century, US	<ul style="list-style-type: none"> Nature-centered (conservation) values are emphasized. Human beings are not seen as the center of moral reasoning. 	<ul style="list-style-type: none"> Evidence of promoting conservation is present.
Ethics of Care	Feminist theorists, 20 th century, US	<ul style="list-style-type: none"> Care for the more vulnerable is valued. Relationships are the locus of ethics. 	<ul style="list-style-type: none"> Evidence of caring for the vulnerable is present. Emphasis on the health of relationships is present.
Falun Dafa	Li Hongzhi, 20 th century, Northeast China	<ul style="list-style-type: none"> Qigong practices lead to health. Truthfulness, compassion, and forbearance 	<ul style="list-style-type: none"> Evidence of truthfulness, compassion, and forbearance is

Name	Origin or Early Principal Proponent	Focus	Metric
		emphasized.	present.
			<ul style="list-style-type: none"> Practices are incorporated.
Family Values	Political strategists, 20 th century, US	<ul style="list-style-type: none"> Emphasis on nuclear family roles as an objective moral good. Patriarchal leadership. Authoritarian discipline is preferred. 	<ul style="list-style-type: none"> Evidence of people in nuclear-family roles is present. Evidence of authoritarian discipline is present.
Kopimism	Isak Gerson, 21 st century, Sweden	<ul style="list-style-type: none"> Communication is sacred, and all information should be shared freely. File sharing is promoted. 	<ul style="list-style-type: none"> Evidence of free information sharing is present.

be subject to analysis. These metrics are given in Table 7. Note that despite the abundance of metrics present in the “Personal assessment” category in Table 6, it proved difficult to work with—as the content here is in general personal. The metric chosen is part of Kantian ethics and can be simplified to a role-based metric, namely, whether the actors fulfilling their roles well. This is taken as equivalent to acting in a fashion that would be categorically applicable. Likewise, *ethics of care* was chosen to represent the sociological field, as caring for the vulnerable could be seen as essential to many of the other metrics, for example, social harmony, social order, transitions, etc. *aesthetics* was chosen to represent a cultural assessment. *evolutionary ethics* and *land ethic* were seen as important in the ecological category, as were *utilitarianism* and *pragmatism* in the quantitative category. These two cases where two ethical perspectives were chosen

Table 6

Metrics for a Selection of Ethical Perspectives Grouped by Category

Category	Analyzed Metric	Topic of the Metric
Personal Assessment	<ul style="list-style-type: none"> • Blissful self-awareness is developed. • Evidence of good thoughts, words, and deeds exist. • Indications of non-violence, pluralism, and generosity are present. • Individual virtue increases. • Compassion, moderation, and humility are cultivated. • Pleasure and delight are abundant. • Emotions are measured and joyful. • Evidence of generosity is present. • Harmony and good fortune are abundant. • Actions are guided by universally applicable notions. • Evidence for people acting in their own self interest exists. • Emphasis on the health of relationships is present. • Evidence of truthfulness, compassion, and forbearance is present. 	<ul style="list-style-type: none"> • Self-awareness • Good thoughts • Good words • Good deeds • Non-violence • Pluralism • Generosity • Virtue • Compassion • Moderation • Humility • Pleasure • Delight • Measured emotions • Joy • Generosity • Harmony • Good fortune • Principled action • Self interest • Healthy relationships • Truthfulness • Compassion • Forbearance
Sociological Assessment	<ul style="list-style-type: none"> • Social order is maintained. • Outcomes promote community well-being and life. • Suffering is minimized in transitions. • Social harmony is maintained. • Transformations occur easily. • Evidence that the community is cared for (charity) is present. • Group interests are improved at the expense of individual interests. • The most competitive have been rewarded. • Evidence of equality is present. • Evidence of caring for the vulnerable is present. • Evidence of people in nuclear-family roles is present. • Evidence of authoritarian discipline is present. 	<ul style="list-style-type: none"> • Social order • Community well-being • Transitions • Social harmony • Transitions • Community well-being • Group interests • Competitiveness • Equality • Cooperation • Family structure • Discipline structure
Cultural Assessment	<ul style="list-style-type: none"> • Sacred rituals are performed well. (x5) • New interpretations or stories have arisen. • An expression of belief is present. • Prayer is present. • Practices are incorporated. • Evidence of free information sharing is present. 	<ul style="list-style-type: none"> • Rituals • Stories • Expressions • Prayer • Practices • Products
Ecological Assessment	<ul style="list-style-type: none"> • Behaviors are in accord with a natural order. • A body of work exists showing an evolutionary pathway for an ethical feature of interest. • Evidence of promoting conservation is present. 	<ul style="list-style-type: none"> • Ecology • Evolution • Conservation

Category	Analyzed Metric	Topic of the Metric
Quantitative Assessment	<ul style="list-style-type: none"> • Outcomes are rated to show their comparative good. • New methods have been tested. 	<ul style="list-style-type: none"> • Accounting • Trial and error

Table 7

Proposed Ethics Assessment Framework

Category	Metric	Ethical Perspective
Personal Assessment	<ul style="list-style-type: none"> • Actions are guided by universally applicable notions. 	Kantian Ethics
Sociological Assessment	<ul style="list-style-type: none"> • Evidence of caring for the vulnerable is present. 	Ethics of Care
Cultural Assessment	<ul style="list-style-type: none"> • Sacred rituals are performed well. 	Aesthetics
Ecological Assessment	<ul style="list-style-type: none"> • A body of work exists showing an evolutionary pathway for an ethical feature of interest. • Evidence of promoting conservation is present. 	Evolutionary Ethics Land Ethic
Quantitative Assessment	<ul style="list-style-type: none"> • Outcomes are rated to show their comparative good. • New methods have been tested. 	Utilitarianism Pragmatism

from a single category occurred because in each case the two had markedly different perspectives.

The framework given in Table 7 will be used to evaluate five cases in the next section: the first three are historical; the last two are hypothetical. Each case was chosen by personal interest, and as a question that might benefit from this type of analysis. Features of each case will be explored through the seven metrics / seven ethical perspectives. Each metric is given one of five ratings: yes, mostly, somewhat, minimally, no. Some positions may be seen as ethical in certain categories but not in others. Thus as an analytic tool this framework may be helpful in identifying areas of agreement and discord in the public discourse related to ethical choices. The analyses are by nature subjective.

Case Studies

1. Ozone

Summary. In 1985 scientists first reported an area of the stratosphere at high southern latitudes where concentrations of ozone seemed to have been dropping since 1975 (Farman, Gardiner & Shanklin, 1985; Solomon et al., 1986). This was and is worrisome (Wang, 2001), since ozone absorbs ultraviolet solar radiation. Without this protection, incidences of skin cancer are greatly increased (Slaper et al., 1996). This phenomenon was termed the "ozone hole" (Newman, 2010; Stolarski & Cicerone, 1974). It was determined that atmospheric chemistry was responsible: chlorofluorocarbon molecules (CFCs) were reacting with ozone to produce other chemicals, thus removing ozone. CFCs are used as a heat-transfer gas in air conditioning and other related technologies, e.g., as a propellant (Anderson et al., 1991; Rowland, 1990). An international treaty (the Montreal Protocol) was established to deal with this issue (Mäder et al., 2010; Velders et al., 2007). A worldwide phasing out of CFCs in industry was implemented, to be replaced by other molecules that act similarly but break down before reaching the stratosphere (Metz et al., 2005).

Ethical question. Was the ban on CFCs by the Montreal Protocol an ethical thing to do? For an analysis, see Table 8.

Table 8

Ethical Analysis of the Question "Was the Ban on CFCs by the Montreal Protocol an Ethical Thing to Do?"

Ethical Perspective	Was the ban on CFCs by the Montreal Protocol an ethical thing to do?	Ethical?
Personal: Kantian	At issue is whether the people involved in creating and implementing the Montreal Protocol acted in accordance with the best conception of their respective roles. To all indications they acted as politicians and scientists should, with no evidence of anything but the highest principles in mind.	Yes
Sociological: Care	At issue is whether the most vulnerable were protected in this protocol. There have been approximately two million fewer cases of skin cancer yearly worldwide because of this protocol (Dijk et al., 2013). The replacement air conditioning chemicals are sourced and produced in a manner similar to those for CFCs, in a manner that may not care for the safety of workers.	Mostly
Cultural: Aesthetics	At issue is whether the process of banning CFCs has produced language, texts or artifacts that contribute to a sense of beauty in the world. Some of the diagrams may be seen as beautiful.	Somewhat
Ecological: Evolutionary	At issue is whether humans evolved to make decisions such as that of the Montreal Protocol. Group dynamics related to hunting large mammals are suggestive that such group decision making is an adaptive evolutionary feature.	Yes
Ecological: Land	At issue is whether environmental conservation has been promoted via the Montreal Protocol. The data show that the hole in the ozone is closing, and thus the environment is being protected. Notwithstanding, the production of both CFCs and the replacement molecules has a negative impact on the environment, promoting extraction-industry practices that are not as sound as they might be.	Mostly
Quantitative: Utilitarian	At issue is whether the Montreal Protocol has produced economic benefit. The cost of switching to replacement gases is more than offset by the savings in healthcare expenditures (in Australia, for example). Globally there has been a net benefit, though locally the costs have been greater than the benefits for regions unaffected.	Mostly
Quantitative: Pragmatic	At issue is whether new techniques were employed that had a reasonable chance of success. Indeed, new molecules were developed and used, and the level of international cooperation was novel.	Yes

2. GMOs in Agriculture

Summary. In the 1970s techniques of engineering foreign genetic material into the genomes of organisms were first developed (Gupta & Singh, 2017). This has led to the creation of a new field of engineering, with use of these genetically modified organisms (GMOs) for specific functions. Bacteria and other microbes are used in novel fashion for drug delivery (Fox et al., 1996), bacteria are engineered with specific genetic markers so that their abundance and distribution can be studied (Leff & Leff, 1996), microbes are engineered to produce medicines, food ingredients, and other chemical compounds (de Vos, 1999), among various medical, research, and technical fields. Within the agriculture sector there have been a wide range of applications as well: for example, pesticide tolerance so that pesticides may be used more efficiently (Padgett et al., 1995); novel biosynthesis pathways to create more nutritious foods, for example, rice with high levels of beta carotene (Beyer et al., 2002); boutique applications, such as producing rabbits that glow in the dark (Tomasula, 2002); or genetic engineering to prevent plant reproduction so that seed needs to be bought each year (Qian et al., 1999). Safety testing of GMOs in agriculture has been carried out for short-term (i.e., less than 10-year) studies with no ill results reported generally (Ash, Novak, & Scheideler, 2003; Nicolai et al., 2014), though there are a few reports suggesting otherwise (Hilbeck et al., 2015; Séralini et al., 2013; Séralini et al., 2014). Test plots have not had good control of seed, and GMO organisms have been found outside of test areas (Haslberger, 2001). Regulation has allowed for widespread use of GMOs for agriculture in some regions of the globe but not in others (Sheldon, 2002).

Ethical question. Is the widespread use of GMOs in agriculture ethical?

Table 9

Ethical Analysis of the Question "Is the Widespread Use of GMOs Ethical?"

Ethical Perspective	Is the widespread use of GMOs ethical?	Ethical?
Personal: Kantian	At issue is whether those responsible for creating and implementing widespread use of GMOs are acting with the best conception of their respective roles. Considering that longterm studies have not been carried out, that studies for vulnerable populations (e.g., children, pregnant women, breastfeeding women, elderly, those with immune compromises) have not been carried out, it would appear that the safety testing is <i>pro forma</i> and does not meet scientific nor health standards. Vulnerable populations are more at risk of adverse effects, as for example during fetal development. Researchers are not inhabiting their roles according to a universal maxim.	No
Sociological: Care	At issue is whether vulnerable populations are considered and cared for by this usage. On the one hand, innovations such as a transgenic variety of rice was developed to supply extra vitamin A to vulnerable populations as a means of protecting health (Dawe & Unnevehr, 2008). On the other hand, longterm safety studies of this and other GMOs have not been carried out for vulnerable populations (e.g., children, pregnant women, breastfeeding women, elderly, those with immune compromises). Of further note: Animals (and plants) have no choice in whether they are created with some anomalous DNA, perhaps to lead lives of increased suffering. The basis and practice of the technology thus violate the ethics of care despite efforts to apply this technology to vulnerable populations.	Minimally
Cultural: Aesthetics	At issue is whether the widespread use of GMOs has produced language, texts, or artifacts that contribute to a sense of beauty in the world. As example, rabbits have had jellyfish DNA incorporated so that they glow in the dark. The possibility for new living artforms exists.	Yes
Ecological: Evolutionary	At issue is whether humans evolved to make and use such innovations as GMOs. Tool-making predates <i>Homo sapiens</i> on the evolutionary tree. Likewise technology use in agriculture and husbandry dates back to pre-history.	Yes
Ecological: Land	At issue is whether environmental conservation will be or has been promoted by widespread use of GMOs. Despite projections that GMO crops often require less water, fertilizer, and pesticide than conventional crops, and that if yields are higher, then less land need be cultivated—for example, a meta-analysis in 2014 found an average pesticide reduction of 37% and yield increase of 22% (Klümper & Qaim, 2014)—it has not. The possibility of species extinction is heightened. For example, the monarch butterfly population that overwinter in Mexico has declined by about 40% from 1999-2010 due to the application of glyphosate for GMO corn and soy crops in the US midwest (Pleasants & Oberhauser, 2013): "The smaller monarch population size that has become the norm will make the species more vulnerable to other conservation threats." The replacement of wild strains of plants by transgenic strains is a likely outcome (Laikre et al., 2010).	Minimally
Quantitative: Utilitarian	At issue is whether the widespread use of GMOs has or will produce economic benefit. There is a billion-dollar global industry in GMOs for agriculture (Lipton, 2015). The potential economic losses from	Minimally

Ethical Perspective	Is the widespread use of GMOs ethical?	Ethical?
	<p>environmental or health impacts may be large, but these have not been determined. There is another economic consideration to make as well. Consider in times past tribal nations would encounter new tribal nations. If they had a desire to create peace, the two nations would develop trade with each other. This trade would allow for peace and stability. In a future wherein humanity encounters another technologically advanced civilization, it may be that our most precious trading commodity will be genomic. Natural genetic information is a record of the interaction between an environment and a population of organisms. The DNA and RNA libraries of life on Earth and in the Solar System may be an invaluable source of potential study and wealth for new alien technologists involved in genetic engineering. Thus destroying organismal biodiversity could be seen as a major utilitarian loss for the future.</p>	
Quantitative: Pragmatic	<p>At issue is whether new techniques are being employed that have a reasonable chance of success. Yes, this is a new technology and brings with it new possibilities. More than 125 million hectares, about 10% of land used to produce food globally, host GMO crops (Qaim, 2009).</p>	Yes

3. Climate Change

Summary. In the 1970s scientists noticed that concentrations of carbon dioxide in the atmosphere were steadily rising (Sawyer, 1972). This has caused alarm since carbon dioxide allows incoming solar radiation to warm the surface of the Earth but absorbs reemitted infrared energy, thus creating a “greenhouse” condition raising the amount of heat retained by the Earth (Pearman & Jäger, 1989). Water (and any gas molecule with three atoms or more) is also a greenhouse gas (Rowland, 2008), but its residence time in the atmosphere is very brief, so that a short-term positive feedback mechanism is not permanently established (Wagner et al., 2003). Notwithstanding, as the atmosphere warms, it can hold a larger amount of water at steady-state on average and establish a conditional, coarse positive feedback as average global temperatures increase. Not so with carbon dioxide, whose atmospheric residence time is more than a decade and whose presence in the atmosphere promotes a stable positive feedback, for example, decreased overall CO₂ uptake by the oceans as stratification increases and long-term oceanic

circulation slows in response to warmer polar waters (Scheffer, Brovkin, & Cox, 2006; Solomon et al., 2009). The added heat is producing climate instability, and eventually climate change (IPCC, 2013/2014). Phenomena associated with climate instability include melting glaciers and ice sheets, an increase in the intensity of tropical storms, an increase in the number of extreme events, for example, droughts and floods, an increased variability to rainfall thereby threatening agricultural systems, increased concentrations of dissolved carbon dioxide in the oceans thereby damaging sea life such as corals, and other organisms (IPCC, 2013/2014). The additional carbon dioxide is coming from two sources: (a) burning of fossil fuels (Marland et al., 2007) and (b) changes to land use that reduce biomass (Höhne et al., 2007). Other greenhouse gasses such as methane—and, for example, ozone created by the chemical reaction of nitrogen oxides on atmospheric oxygen—are also added to the atmosphere in increasing amounts from human activities exacerbating the greenhouse condition (El-Fadel et al., 2001).

Ethical question. Is it ethical for fossil fuel companies to continue to develop new fossil fuel reserves? For an analysis see Table 10.

Table 10

Ethical Analysis of the Question “Is It Ethical for the Fossil Fuel Companies to Continue to Develop New Fossil Fuel Reserves?”

Ethical Perspective	Is it ethical for the fossil fuel companies to continue to develop new fossil fuel reserves?	Ethical?
Personal: Kantian	At issue is whether those responsible for developing new fossil fuel reserves are acting with the best conception of their respective roles. Considering the scope of the potential damage to the economy, an argument can be made that fossil fuel companies ought to see themselves foremost as energy companies. If their mission is to develop energy sources, they could be developing energy sources that do not contribute to climate change. Thus these people are not acting with the best conception of their roles, despite fulfilling one aspect of that role, namely furthering the development of energy sources for short-term benefit.	Minimally
Sociological: Care	At issue is whether vulnerable populations are considered and cared for by the further development of fossil fuel reserves. The economically disadvantaged are at higher risk for bearing the consequences of extreme events as they lack resources to recover from catastrophe. The Intergovernmental Panel on Climate Change (IPCC) suggests that there will be millions of lives lost among the less advantaged because of climate change.	No
Cultural: Aesthetics	At issue is whether the continued development of new fossil fuel reserves will produce language, texts, or artifacts that contribute to a sense of beauty in the world. Currently, about 80% of the global economy depends upon fossil fuels. The energy produced does go into projects that increase a sense of beauty in the world, despite the aesthetic damage caused by extractive industries. However, by persisting in developing fossil fuels, civilization may be disrupted completely from agricultural failure, and these cultural benefits lost. Without stable rainfall patterns, widespread agriculture will not be possible, nor will civilization.	Minimally
Ecological: Evolutionary	At issue is whether humans evolved to persist in technology past a point of group safety—whether there is an evolutionary benefit in spoiling an ecosystem. Examples of overhunting abound in pre-history (Burney & Flannery, 2005). The megafauna extinction may be due to human hunting. There may be an evolutionary advantage for a highly adaptive species to negatively impact its environment, since, being so adaptive means that it will have a competitive advantage in the ensuing period of transition.	Yes
Ecological: Land	At issue is whether environmental conservation will be promoted by the continued development of fossil fuel reserves. Despite human reliance on them, extraction industries degrade natural lands and release harmful chemicals into the environment that aggregate in new places, e.g., in the Arctic and Antarctic (Banerjee, 2012). Combustion processes create new forms of pollution, e.g., acid rain. Flora and fauna are affected. Continued development likewise threatens entire ecosystems with changes to phenology and rainfall.	No
Quantitative: Utilitarian	At issue is whether the continued development of fossil fuel reserves will produce economic benefit for these companies and for human civilization. The short term gains are very high. Fossil fuels are a <i>sine qua non</i> of the global economy. Yet, the long term outlook is uncertain and possibly catastrophic.	Minimally

Ethical Perspective	Is it ethical for the fossil fuel companies to continue to develop new fossil fuel reserves?	Ethical?
Quantitative: Pragmatic	At issue is whether new techniques are being employed that have a reasonable chance of success. New techniques are being developed for fossil fuel extraction, e.g., deep-water extraction, shale oil extraction, tar sands extraction (Hinkle & Batzle, 2006). Notwithstanding, opportunities to develop novel energy sources are being ignored.	Somewhat

4. Astrobiology

Summary. Living organisms may be discovered on other planets in our solar system or in other places in the universe. Humans are actively exploring and would benefit both morally and materially from having a clear idea of how to interact with newly discovered life.

Ethical question. If Martian microbial life is discovered, is it ethical for humans to colonize Mars even if that means spoiling the environment of the microbes? For an analysis, see Table 11.

Table 11

Ethical Analysis of the Question "If Martian Microbial Life Is Discovered, Is It Ethical for Humans to Colonize Mars Even If That Means Spoiling the Environment of The Microbes?"

Ethical Perspective	If Martian microbial life is discovered, is it ethical for humans to colonize Mars even if that means spoiling the environment of the microbes?	Ethical?
Personal: Kantian	At issue is whether those responsible for colonizing Mars are acting with the best conception of their respective roles if microbial life is discovered there. There are other planetary bodies that could be colonized first, e.g., the Earth's Moon. It would perhaps be preferable to colonize a place where no life is known rather than one wherein life has been discovered. This is similar to the argument that drives archaeologists to reserve a portion of a site and not dig there (Wylic, 1999). At some later date new technology may make a study more fruitful. Thus digging a site completely has the potential to lose valuable information. Likewise, in space exploration, opting to colonize a place wherein microbial life has been found does not allow for future generations to employ new study techniques in the future. The opportunity is lost.	Minimally
Sociological: Care	At issue is whether vulnerable populations are considered and cared for by the colonization of Mars if it would disrupt microbial life found there. In general, there is a class of people who are opposed to microbial ecosystems disruption on two bases: (a) some microbes are essential for other ecologies to thrive, e.g., phytoplankton in the oceans, or bacteria in the gut; (b) respect for the unknown and its inherent new possibilities. If microbes on Earth had been destroyed a few billion years ago, there would be no humans—so it is a real issue that microbes may lead to some advanced life forms at some future date even considering the harsh environment of the Martian surface. However, it might be noted that the conditions for evolution rely on differentials within, and changes to the environment (Ilardo et al., 2015). Current knowledge of evolutionary processes is not robust enough to make that calculation with confidence.	Somewhat
Cultural: Aesthetics	At issue is whether the colonization of Mars, despite disrupting microbial life there if it were found, would produce language, texts, or artifacts that contribute to a sense of beauty in the world. Doubtless the colonization of Mars would be accompanied with an immense outpouring of cultural artifacts and stories that would add to the beauty of the world.	Yes
Ecological: Evolutionary	At issue is whether humans evolved to disrupt native ecosystems during colonization attempts. Examples of introduction of non-native species abound in pre-history. Many ancient forests, for example, were managed by native peoples to favor nut production. There has been an evolutionary benefit to introducing new species even at the expense of the old.	Yes
Ecological: Land	At issue is whether environmental conservation will be promoted by colonization of Mars despite disrupting microbial life there if it were found. Clearly the impetus is not one of increased local conservation on Mars.	No
Quantitative: Utilitarian	At issue is whether the colonization would produce economic benefit for the companies or governments involved in the work. While space exploration has always brought with it technological innovation that has had novel application and economic benefit, the immediate costs	Minimally

Ethical Perspective	If Martian microbial life is discovered, is it ethical for humans to colonize Mars even if that means spoiling the environment of the microbes?	Ethical?
	<p>have not always been offset by profits. There is a further point of note that is related to the utility of colonization. Consider in times past tribal nations would encounter new tribal nations. If they had a desire to create peace, the two nations would develop trade with each other. This trade would allow for peace and stability (van der Dennen, 1998). Now consider a future wherein humanity encounters another technologically advanced civilization. It may be that our most precious trading commodity will be genomic. The DNA and RNA libraries of life on Earth and in the Solar System may be an invaluable source of potential study and wealth for new alien technologists involved in genetic engineering. Thus destroying organismal biodiversity could be seen as a major utilitarian loss for the future.</p>	
Quantitative: Pragmatic	<p>At issue is whether new techniques are being employed that have a reasonable chance of success. Clearly a colonization effort of Mars is a novelty and may have a reasonable chance of success if the technology can support it. If other possibilities exist that would protect Martian microbes if they were found, and these possibilities were ignored, then the mission could be seen as shirking the exploration of new techniques.</p>	Somewhat

5. Machine Life

Summary. Machine learning is pervasive. Training sets are used to promote reasonable outcomes, and new strategies are being developed to promote more efficient computation. Despite major challenges to machine life—for example, the inability of a machine to see beyond specific tasks; lack of a developmental pathway—it is something that attracts research interest. Moreover, the development of quantum computing may provide a novel mode of seeing beyond specific tasks (Kak, 2000). A quantum bit, or *qbit*, may take on a potentially infinite number of values. Thus ranking schema performed by a quantum computer may be continuous rather than discrete, opening up the possibility that non-constructive mathematics will guide machine decision-making. Thus there is a potential for machine life.

Ethical question. Is it ethical for humans to develop autonomous living machines? For an analysis, see Table 12.

Table 12

Ethical Analysis of the Question "Is It Ethical for Humans to Develop Autonomous Living Machines?"

Ethical Perspective	Is it ethical for humans to develop autonomous living machines?	Ethical?
Personal: Kantian	At issue is whether those responsible for developing autonomous living machines would be acting with the best conception of their respective roles. To give an example: breeding dogs can be seen as a positive act that is susceptible to abuse of the animal. It is not clear what the parameters would be to train autonomous living machines not to be destructive of humanity. Thus a role-specific analysis depends upon how the development of autonomous living machines is to take place. It is conceivable that their development takes place for economic gain without safeguards.	Somewhat
Sociological: Care	At issue is whether vulnerable populations are considered and cared for in the development of autonomous living machines. The machines themselves can be seen as a vulnerable population, as can any living organism that their development impacts. It is conceivable that these issues would all be addressed positively, and that autonomous living machines would be developed specifically to care for other vulnerable organisms. The opposite is also conceivable.	Somewhat
Cultural: Aesthetics	At issue is whether developing autonomous living machines would produce language, texts, or artifacts that contribute to a sense of beauty in the world. Autonomous living machines would be a technological marvel. Clearly there would be beautiful cultural artifacts created in this process, perhaps some by the machines themselves.	Yes
Ecological: Evolutionary	At issue is whether humans evolved to create new life. There are examples in agriculture, e.g., corn, and animal husbandry, e.g., dog breeds, of humans interacting with and creating new organisms for a host of reasons, including many that led to competitive advantages, i.e., stable food supply. These exist despite challenges created by such efforts, as for example animal domestication leads to new infectious agents being present, e.g., swine flu, via cohabitation.	Yes
Ecological: Land	At issue is whether environmental conservation will be promoted by developing autonomous living machines. Computer infrastructure takes a large toll on the environment in terms of energy usage, resource extraction, and production pollution (Le et al., 2010). On the other hand, autonomous living machines may perhaps be used in processes that would allow for more land conservation, or to recast other industrial processes in a manner that allows for better environmental protection. Yet at this point machine production is based on extractive processes, and it is not clear that the presence of autonomous living machines would supplant resource extraction in other industries.	Minimally
Quantitative: Utilitarian	At issue is whether the development of autonomous living machines would create economic benefit. Clearly an abundance of a new work force would be of economic benefit.	Yes
Quantitative: Pragmatic	At issue is whether new techniques are being employed that have a reasonable chance of success. The development of autonomous living machines would create new ideas about our own biology as well as find new applications to established areas of knowledge.	Yes

Discussion

The framework developed in this paper is useful for examining controversial issues using different perspectives, and the distinctions drawn out by different ethical perspectives are preserved and highlighted. Thus this type of framework may find widespread application and enjoy a measure of popularity in helping to make decisions and communicate how those decisions are arrived at. It is meant to increase respect for differing viewpoints. There are a few pitfalls, however. Most notably, the different ethical metrics do not fit into a multiple-criteria decision making process. This theme is detailed below.

First, the categories (personal, sociological, cultural, ecological, quantitative) and the seven chosen ethical perspectives within them (Kantian, care, aesthetics, evolutionary, land, utilitarian, pragmatic) were found via an inductive process using only a small portion of extant ethical perspectives, and via an informal codification of their characteristics. While the author of this article or some readers may be pleased with the results, as the framework seems to include distinct and interesting perspectives, other readers may find reasonable fault with omissions or with what was included. The decision of what to include forms the basis the reported outcomes. Thus the framework itself is not categorically valid and has not been validated by means other than checking briefly for an outward appearance of thematic coverage and consistency. Of greater certainty is the idea that this type of framework is possible, and the description of this instance of it has given some insight into how a framework might be constructed—though it is a tool for looking at perspectives respectfully rather than for coming to rigorous, consistent conclusions.

Second, there is a tendency towards reductionism that this framework promotes. For example, the five ratings for the metric (*yes, mostly, somewhat, minimally, no*) can be arbitrarily scored as: 1, 0.75, 0.5, 0.25, 0. Then a single score can (arbitrarily) be generated for all the case studies explored: 0.82, 0.54, 0.32, 0.5, 0.75, and then translated back to the original questions, for example, the widespread use of GMOs is somewhat ethical (0.54). However, this preserves none of the perspectives that went into creating the score, nor emphasizes that the case study ratings that were given are subjective. Further, there is no clear way of validating comparative ethical perspectives. A score of 0.75 in aesthetics would in no way be equivalent to a score of 0.75 in Kantian ethics—since each perspective has a unique basis, and these bases are not monotonically nor perhaps even algebraically connected. It is also clear that a measure of central tendency (such as an arithmetic mean of scores) does not capture what one would like to capture in an ethical analysis. Perhaps it would be the case that any ethical question with two zeros could be seen as unethical. Or perhaps any with three scores of 0.25 or less could be seen as unethical. It is not clear how this would be validated. Likewise, it is the kind of rubric that could easily be picked up by news media and reported, for example, “Colonizing Mars despite having found microbes there is approximately as ethical as the widespread use of GMOs in agriculture”—and this would serve to further divorce the general public from a clear understanding of what science is and can do. A more appropriate summary of the ethical analysis is presented in Table 13. This type of table can be used as a quick reference to compare different proposals from different ethical perspectives at the same time.

Table 13

Summary the Ethical Analyses of the Case Studies Presented in This Chapter

Ethical Question	K	C	Ae	E	L	U	P
Was the ban on CFCs by the Montreal Protocol an ethical thing to do?	Yes	Y	-	Yes	Y	Y	Yes
Is the widespread use of GMOs in agriculture ethical?	No	N	Yes	Yes	N	N	Yes
Is it ethical for fossil fuel companies to continue to develop new fossil fuel reserves?	N	No	N	Yes	No	N	-
If Martian microbial life is discovered, is it ethical for humans to colonize Mars even if that means spoiling the environment of the microbes?	N	-	Yes	Yes	No	N	-
Is it ethical for humans to develop autonomous living machines?	-	-	Yes	Yes	N	Yes	Yes

Note. Yes = Yes, Y = Mostly, a dash = Somewhat. N = Minimally, No = No, K = Kantian, C = Care, Ae = Aesthetics, E = Evolutionary, L = Land, U = Utilitarian, P = Pragmatic.

Thus the framework presented in this paper is seen as an interesting addition to the field of ethics as it seems useful in promoting respectful dialogue, but caution should be taken in its usage. The development of the framework itself—involving an exploration into culture, language, religion, science, and the history of ethics—is an interesting and worthwhile endeavor. The utility of looking at ethical issues from complementary perspectives is of obvious value if one hopes for an integrated society working towards cooperation.

CHAPTER IV: DATA AND ANALYSIS

Details of the data and analysis follow the order in which the analysis occurred. The Skype group discussions were analyzed first so that impressions would be fresh in the mind. Within both sections below, the text: (a) describes the data and analysis; (b) presents the results; and (c) presents a validation procedure for the results. Discussion of the results, plus recommendations for policy makers, and sample lesson plans will be presented in the subsequent chapter.

Skype Group Discussions

Skype discussions occurred on January 18, 2017, and from January 18 to 21, 2017, related data were created. A series of three sets of notes were generated. The first were notes related to the content of each Skype meeting. There were three meetings that day. The first was with myself and one participant. He was calling from the midwest and called four hours before the set time, since the Pacific time zone is two hours behind, and instead imagined it to be two hours ahead. We talked, and I took notes of the conversation. The second was a call between myself and another participant to see whether her Skype was working. I again took brief notes of our conversation. The third was the actual focus group with myself and two participants. I took notes of this meeting as well. A third participant was unable to join because of privacy settings, and the impression left with me was that she was comfortable with the outcome, as she had other pressing work. Thus there were notes created about the content of the three meetings via Skype that occurred on January 18, 2017.

A second set of notes were created as a focused reflection. The process involved typing "Impression ONE" on a document and starting to reflect via the written word on

the underlying structure of the main group discussion as well as its content. Writing continued until either there was a thematic shift in the writing, at which point "Impression TWO" was written and more text created, and again if there was a new thematic shift, or until it was clear that a novel and deep set of insights had been gathered and that a complete picture had been reached. This method produced five reflections.

A third set of notes was a focused reflection organized around the theme of mathematics, identified as important in the previous set of notes. Writing continued until it was clear that a novel and deep set of insights had been gathered and that a complete picture had been reached.

The three sets of notes related to the Skype group discussions described above are labeled here as:

1. Content notes, in three parts.
2. Reflection notes, in five parts.
3. Mathematical reflection notes.

1. Content Notes

First discussion. The first discussion centered on introductions between the researcher and one of the participants. A comparative analysis of ethical perspectives present is given in Table 14.

Table 14

Comparative Ethical Perspectives Evident in the First Discussion

Ethical Perspective	Observation from the First Discussion
Personal: Kantian	<ul style="list-style-type: none"> • Takes his role of professor seriously, evidenced by caring for a former student in medical distress. • Takes his role of professor seriously, evidenced by willingness to participate in discussion.
Sociological: Care	<ul style="list-style-type: none"> • Influenced by my status as a vulnerable graduate student in his willingness to participate. • Awareness of the power of pharmaceutical companies to influence medical practice.
Cultural: Aesthetics	<ul style="list-style-type: none"> • Wore a headset, evidencing his care about the quality of his experience. • Well-groomed appearance.
Ecological: Evolutionary	<ul style="list-style-type: none"> • Awareness of model of evolutionary benefit for certain features in families. • Awareness of traditions of mind-expanding drug use.
Ecological: Land	<ul style="list-style-type: none"> • Not much evidence of land / environment in the interaction.
Quantitative: Utilitarian	<ul style="list-style-type: none"> • Strong evidence of purpose in his research focus that includes development of a novel drug. • Strong evidence of purpose in his patent application. • Strong evidence of purpose in his care in language use in describing his work.
Quantitative: Pragmatic	<ul style="list-style-type: none"> • Strong evidence of purpose in a research focus on novel techniques.

Subjectively, I was able to formulate an assessment of the participant after analysis as: pragmatic > utilitarian > tie with: evolutionary, aesthetics, Kantian and care > land. My analysis here is strictly qualitative and inferential. Technology is able to do a similar task, generating a personality profile for marketing purposes, for example with the IBM Watson Developer Cloud: Personality Insights (IBM, 2017).

As this is an emergent analysis, I next undertook a thought experiment. I explored the notion of adapting this type of automated personality analysis to a comparative ethics framework. I noted that personality analyses are already being pursued for marketing. I

suggested to myself the idea of pursuing personality analyses for political processes. I suggested to myself that the result might be useful for established political parties to engage in dialogue with their constituents and identify those who would be willing to affiliate for the sake of political organizing. I suggested to myself that this is already being done. I wondered whether this would help humanity. I inferred that this would just be a case of doing more of the same, namely, fragmenting people into groups. Next, I wondered what a strong organizational decision-making process would look like that did not fragment people into groups. I suggested to myself that these seven areas may be adopted as a rubric for discussion. I concluded that if one wants to divide people into groups, one could rate them on such personality scales; if one wants to get people working together, one could teach them to recognize the different perspectives present in each person, and address each one of these perspectives in an official capacity. I further concluded that it probably does not matter which seven-or-so ethical perspectives are used, or the language of the usage, since usage changes over time. What seemed important to me was that official correspondence be imbued with a formal address to complementary perspectives in a manner that recognizes the validity of all of them.

Second discussion. I spent most of the call recounting: (a) the state of astrobiology and how it is poised for success; (b) my work in comparative ethics; (c) the work of the other participants who would be involved in the Skype call later that day; (d) my poster at the Gordon Research Conference in Galveston, (e) my abstract to AbSciCon 2017. I noted that the participant seemed most concerned that she know the purpose and function of the interaction. As her questions were strictly role-based, I took these as implicit evidence of a Kantian ethical framework. I suggested to myself further that if a

Table 15

Summary of the Findings of the Content Notes

Context	Result
First discussion content notes.	Personality ratings tend to assign people into groups and are divisive.
First discussion content notes.	Recognizing the different perspectives present in each person tends to help people work together.
Second discussion content notes.	Kantian ethics is an appropriate framework from which to address people whose actions show that they are concerned with maintaining a professional role.
Second discussion content notes.	Aesthetics may be a universal framework from which to address a person, to the extent that communication always relies on perceptions.
Second discussion content notes.	The other ethical approaches described herein (care, evolutionary, land, utilitarian, and pragmatic) each are conditioned on other parameters, thus the perspective may not be readily accessible.

person is only asking questions, one may assume that Kantian ethics is an appropriate framework from which to address them, as they are inhabiting a professional role.

Likewise, it struck me that aesthetics may be a universal framework from which to address a person, to the extent that communication always relies on perceptions. The other ethical approaches described herein (care, evolutionary, land, utilitarian, and pragmatic) each are conditioned on other parameters, thus the perspective may not be readily accessible.

Third discussion. The conversation was a bit adversarial between the two participants, such that it inspired me to focus even more strongly on this study of comparative ethics. Both participants had a brilliance about them. I aim to develop my skill more in facilitation. The reflection notes and mathematical reflection notes that follow each address the content of this third discussion.

Summary. The results of the content notes are summarized in Table 15. All findings were arrived at by induction.

2. Reflection Notes

Impression one. While describing the seeds of conflict between the two participants in the third discussion, I found myself focusing on the assessment I had done earlier. [This is presented above in the First discussion section.] I noted that the participant seemed impassioned. I wondered about my own biases, namely that I seem to value a personal, internal ethic. Perhaps the system I have presented, from Kantian Ethics > Ethics of Care > Aesthetics > Evolutionary Ethics and Land-based Ethics > Utilitarian Ethics and Pragmatic Ethics (i.e., Personal > Social > Cultural > Ecological > Quantitative) are structured in this fashion because of my own bias. I am biased in favor of people following a role-based framework. I am so committed to a role-based ethic that—in conversation—I will promote "role-based psychology" as a path to good mental health. Yet I wonder how valid my assessment is. I wonder whether my perspective would be valid for anyone else.

Likewise, I noted how very noisy the conversation was in talking with this participant, and how very quiet it was in talking with the other, after the first had left the call. My impression on thinking of this was centered around mood. I think in talking with the first I was trying to follow the arguments and see how I could help to extend them. I felt that I did not have a very good sense of whence the perspective arose, that we were not necessarily communicating constructively. Talking with the second reminded me that the mood is fundamental in learning, and that my role can be made stronger in establishing a mood. My work is a training. I want to be a better facilitator. It is always possible to find something to help establish a better mood. This leads me to imagine that perhaps the study of comparative ethics is related to a certain mood that allows for it. I wonder what would characterize such a mood. It would doubtless need to have communicative features—modes of communication that allow for the mood to be deepened or maintained for the benefit of those participating in the dialogue.

Impression two. Both participants in the third discussion were concerned that we talk explicitly about ethics. I did only a fair job of describing my research method, which involves impressions and language analysis in its action. They were concerned that my topic wasn't being covered. Let me then go back to this. I guess my impression, the starting ground of where I am with the ethics of astrobiology and machine intelligence is that much of the work is done in deference to a perceived norm. People write grants and get money so that they can work, and this process normalizes their intentions and smoothes over something... and that something, from my perspective, resides in the deep caring that people do with each other in order to banish aggression. Deeply, my thoughts are that connections between people fail because an aggressive spirit takes root. By extension, it is unclear to me how those researching new life will be able to root themselves into

such a spirit. The result will be a poorly-conceived framework for dealing with new life, one that will not protect it decently.

Note well that one participant in describing his outlook towards his research expressed fears of centuries wherein we have lost our humanity. Likewise the second described his joy in being a part of a national spirit that values the other and is rooted in pluralism. But... In these observations, in these conversations, I wonder what is it, if anything, that I am adding. I wonder whether I am just promoting a deepening of awareness of mood. I wonder whether my major effort is one of aesthetics, wherein I may promote the focus on beauty of communication—leading to deeper communication. I wonder whether these thoughts are really organized around any principle. If I choose to say that aggression is the most dangerous thing, perhaps it is not helpful. Perhaps the better course is in hiding the spirit of the thing in riddles, as in a game. Perhaps the focus ought to be on an empty cup. Let me present a cup for others to fill.

But to return, let me say something about the ethics of those who research machine life and life's origins. I observe that researchers deeply value their field. They have a strong sense of wanting to act with respect towards the complexity that they engage with. I am caught with the image of a tradesperson in my mind's eye, painstaking in how they engage in their work. Keeping an open mind yet filled with the details of the tasks that arise. What somber, solitary life that crafts itself! And yet the emotion—and the one participant had described a self-effacement in the sciences, wherein feelings are not seen, not heard, not deemed worthy of study—the emotion of new discovery is very strong in all. If I have discovered that these researchers are human... I wonder whether I have discovered anything of note. And yet the one participant identifies a problematic. He identifies an area wherein discovery is not allowed. I am not afraid here. I like the framework I digested, the one wherein mathematics is defined as the study of mental objects whose properties are reproducible, and all other mental objects are seen as personal and valid, inhabiting the realms of philosophy or religion or other personal spheres, such as whom a person loves.

Indeed, I will see my role strengthened in this endeavor. Perhaps the greater part of my work is to promote this framework wherein the mathematical and personal can be used to build respect for each.

Impression three. Let me try again to explore comparative ethics, and specifically what may be said about those who work in astrobiology and machine life. I imagine a future. I look deeply towards a future wherein different modes of being are employed based on the context of the environment, task, or social world. If what is presented is personal, then a mode of being that promotes personal health is employed and strengthened. If what is presented is mathematical, then a mode of being that promotes abstraction and sacred spaces is employed and strengthened. If what is presented is scientific—in its broad sense to include all of technology—then a mode of being that promotes interaction and useful spaces is employed and strengthened. In this I think I have moved the sacred from the personal to the mathematical. I can assert that abstraction is in general only possible by some leap of faith... some recourse to the sacred.

We can hear octaves. In the auditory experience is the impression of mathematics. This sacred (musical) space is infused with mathematics. And perhaps my impression of the work, the potential to find new life in silica or outward in new planets, that success and in fact ethical strength will arise from how sacred the course of action is. Then the rubric that is most useful is a mathematical one. The questions to be asked are mathematical, namely, whether the arguments in favor of a certain ethic or other can be based on conditions that are reproducible. Likewise, it remains to be asked whether ethics are something that is strictly personal, or whether there is a mathematical component inherent as well.

I hope that I am able to make this case strongly. I hope that I will be able to show that in each of these ethical systems, whether Kantian... to Pragmatic, there is inherently something personal, and also inherently something mathematical, i.e., mental objects with reproducible properties. Success depends on using language in a way that communication of that shared understanding allows for a deepening of mood. Or perhaps not. Perhaps my aim needs to be in identifying how mental objects might have reproducible properties. As a teacher I have certainly spent much time in wondering what actions I might take to produce an impression of a mental object—a concept. The underpinnings of concept, i.e., what is the concept of a concept, are not beyond exploration. One could be as a Scholastic, and describe all that is not involved in a concept, i.e., everything that is not a concept. The work of this is left to the reader as an exercise. [Humor intended.]

Impression four. In brief: (1) A series of distinct ethical frameworks were described in the dissertation earlier. (2) Each of these allows for abstraction—allows a person to see the concepts behind each ethical system to the end that those ethical systems may be seen as abstract and not purely personal. (3) There is a scientific ethic I think I do see in researchers—not just in this brief Skype discussion but also in my interactions—that researchers care for the details of their work.

If anything, the biggest offense and shock to myself as a scientist—in noting that someone has falsified data (and this is not unheard of)—is that it implies that the work is seen by them as formulaic, and that the formula can be subverted. How far from actual practice this is! Perhaps there are details missing in the training of some scientists, in their schooling that prevents them from noting the importance of care with details, with gathering enough information so that reproducibility is possible. Again, it involves some mathematical structure emerging from the personal.

On the positive there is this attention to detail such that no relevant datum will be lost, and any assertion may be traced back and reconstructed from its bases. On the negative there is a sense that the larger picture has been lost, that the intensity required for the work prevents a mood of mind expansion, that scientists lack heart.

Perhaps this is so. Perhaps grading papers and failing students allows a person to set themselves as a sieve to process their fellows. What potential may be

Table 16

Summary of the Findings of the Reflection Notes

Context	Result
First impression reflection notes.	Mood is fundamental in learning.
Second impression reflection notes.	These people are painstaking in how they engage in their work and in their attention to detail.
Third impression reflection notes.	Mental objects with reproducible properties may arise by reflecting upon the personal.
Fourth impression reflection notes.	Academia promotes misanthropy in its role as gatekeeper.
Fourth impression reflection notes.	Academia also promotes a social compact in its role as gatekeeper.
Fifth impression reflection notes.	The fields of machine life and astrobiology value creativity.

lost by lack of sufficient encouragement is difficult to say, and yet it is clear that professors don't see their role as the same as that of teacher. Perhaps the willingness to draw the line and fail those who cross it deafens the ears of scientists to some potential connection with their fellows. This points to character and emotional health, and it will be asserted by many that without a rigorous sieve there can be no growth forward... and yet one also knows of developmental needs and that frameworks do not need inherently to be adversarial, that demands need not be deflected, but may instead be met with more attention to detail. It is time that is the greatest enemy of professors. There is not enough time to do what needs doing.

Grades protect students from being subject to arbitrary whims of those who supervise their work. Caring relations between supervisor and student can propel students much further in life than mere grades. Perhaps the space for each resides in abstraction. Again I return to the question of whether there is anything novel or worthwhile to see in the role of these scientists in particular, dealing as they do with life and consciousness. If at first I identified caring attention to details as a characteristic, perhaps now I will identify misanthropy, i.e., a difficulty in caring for the community, as another characteristic, melded as it is with its opposite, i.e., a social compact that is very high.

Impression five. Caring for details, misanthropy, social compact—these are things that characterize academics generally perhaps. I wonder, though, of those who work in this area of research, origin of life, whether found or created. As it is a novel area, I think I am on safe shores to say that creativity is highly valued here. As both participants related, there is a feature about scientists that resides in their creativity. We in this field are creative. We do not want to be bound by what

is known. And we are reaching to the limits of science. That reach involves creativity.

Taking the above three characteristics plus creativity, I wonder whether there is something that may be said related to comparative ethics. Probably not. Let there be no final word. Let the work continue unbounded.

Summary. The results of the content notes are summarized in Table 16. All

finding were arrived at by induction.

3. Mathematical Reflection Notes

Mathematics as a topic presented itself several times in the prior set of reflections on the focus group. Mathematics is the theme for this reflection. The aim is to imagine the influence of mathematics on the focus group.

All four of us, myself and the three discussion participants, are trained in mathematics. Two are trained in computer science. A third models the origin of life in relation to mineralogy and does so in a mathematical framework. I do exploratory looks at various things, e.g., musical scales, to see their mathematical underpinnings, and do other research in mathematics.

Mathematics can naturally inhabit the worldview of adherents of any of the seven ethical systems I have presented. Certainly Kant was a trained natural philosopher, and those writings have a mathematical beauty to them. They treat mathematical objects. And utilitarianism makes use of mathematical objects in making its judgement. Even a land ethic may be seen as mathematical if the Spirit of Nature that inhabits the world can express creation in the mathematical interplay of relations between the elements of nature.

I suppose that the fundamental is thus mathematics—that mathematics, i.e., the study of mental objects with reproducible properties, is the fundamental force behind ethical systems. What touches a person about ethics is personal. Thus our supposition is false. Ethics is personal, and not strictly mathematical. The fundamental is both personal and mathematical. Ethical systems are a fusion of personal and mathematical insights. If I am not confused in this, let me assert that ethical systems rest upon mental objects with both reproducible and non-reproducible properties.

We engage with each other from a personal space, and yet try to find the mathematical within that space to communicate our values. That is an ethical system in its own right, perhaps. And in looking here at what is personal, perhaps we are searching to extend our personhood via communicating with each other, to deepen our understanding of what it is to be ourselves, and what the nature is of the relationship we have with ourselves.

This makes me think of the emptiness that is described by the Buddha, that we lack a separate self—that our sense of self is a construction. Indeed, one wonders where the self is to be found. If it is in the body, then one wonders what happens to the self once the body is no longer a living body. And if the self is just

a construct, then... one wonders what that implies related to ethical duties towards machine life and extraterrestrial life.

Perhaps each of the above is different. Perhaps we will find that with machines we will need to accept that life can be constructed, and that there will be a criterion beyond which living machines are accorded rights. I am pleased with Dr. Gerard Jager's criterion of dual closure (both structural and functional) as an example of such a criterion... and thus we are nearly there, since machines can write code for themselves to run... Total automation is not far off I imagine. And once this stage is reached there will need to be rights conferred.

Next I wonder whether food is a human right. I wonder whether machines will be accorded a right to electricity. It will probably fall into the same category of *humanity* to grant these resources whenever possible. And yet here is where comparative ethics comes to the fore. Humans are not necessarily afforded rights. People can be killed arbitrarily according to some ethical systems, for example, e.g., soldiers—and indeed humanity struggles with its inheritance of competing values. If humans are really accorded life, liberty and the pursuit of happiness (to give a US-centric example), then living machines ought to be as well. And so ought animals. Yet animals are not, based on an argument of hierarchy of complexity. One wonders whether humans really are more valuable than dolphins in all circumstances, and whether a valuation is really possible. Thus one is left with the same unanswerable question when attempting to extend rights to living machines or extraterrestrials.

With extraterrestrial life, the premise will likely be that they are of course living, and yet we are no further to our goal of determining what rights ought to be extended to them without recourse to some other framework. And that framework is likely to be facility in using perspectives from competing ethical systems. Arguments may be made, for example, to extend all rights in a certain fashion to extraterrestrial life, based on utilitarian or role-based or care-based arguments, just as they are for animals.

What is interesting here now is the mathematical bases of these competing ethical systems. It occurs to me to look at the Lie Algebras that may match the kinds of arguments that each of these ethical systems tends to make. Lie Algebras look at how operations are conducted on the mathematical structures of a system. A study of this nature would not allow for a single, unified algebra... each is a separate entity. And yet the work would be interesting for generating some insight or clarity about how each of these seven ethical systems operates.

Again we are left with an open-ended question: How is new life to be treated, if we wish to be ethical beings? Again we have the same answer, that competing perspectives from different ethical systems can help people to make well-informed choices when deciding.

Summary. This reflection has identified the following interesting insights: (a) all of us participating in the group are trained in mathematics; (b) ethical perspectives have both personal and communicable components; (c) if living organisms are to be protected,

Table 17

Summary of the Findings of the Mathematical Reflection Notes

Results from the Mathematical Reflection
All of us participating in the group are trained in mathematics.
Ethical perspectives have both personal and communicable components.
Machine life will need to be protected once it has reached a threshold of life, thus a definition for life will need to be developed that can mark this stage, and functional autonomy may be this marker.
How humans decide to treat animals is similar to how humans will decide to treat machine life and extraterrestrial life.
Lie Algebras may be able to model different ethical frameworks, and lend some insight into their operation.
An appreciation for different ethical perspectives allows for well-informed choices when faced with questions of rights.

machine life will also need to be protected once it has reached a threshold of life, thus a definition for life will need to be developed that can mark this stage, and functional autonomy may be this marker; (d) how humans decide to treat animals is similar to how humans will decide to treat (larger-than-microbial) extraterrestrial life and living machines; (e) Lie Algebras may be able to model different ethical frameworks, and lend some insight into their operation; and (f) an appreciation for different ethical perspectives allows for well-informed choices regarding questions of rights. These insights are presented in Table 17 for later comparative analysis. For a discussion of the differences between personal and communicable information, see Table 4 and the text adjacent to it.

Word Count Validation

The three sets of notes were separately added to the website Wordle (Feinberg, 2016) to generate a wordcount, which is a list of all the words and their frequencies in a text. Articles, prepositions, conjunctions, names, the verb *to be* and its conjugations,

Table 18

Alphabetical List of Words Used Three or More Times in the Content Notes

Noun	Verb	Adjective	Adverb
Aesthetics	address	able	only
analysis	Asked	comparative	
Awareness	call	each	
Care	care	ethical	
consideration	Described	Evolutionary	
considerations	does	Kantian	
data	doing	Land-based	
discussion	use	mental	
drug		mind-expanding	
Ethic		other	
ethics		political	
evidence		Pragmatic	
experience		same	
focus		Strong	
framework		Utilitarian	
humanity			
interaction			
Land			
notes			
people			
person			
personality			
purpose			
role			
student			
systems			
time			
work			

pronouns, numbers, and days of the week were excluded. All other words used three or more times in the content notes are listed in Table 18. The list of words was double-checked to ensure that upper- and lower-case versions of a word were tallied together and included if it appeared three or more times, in which case the lower-case version was

added. Reading through these words and comparing them with Tables 14 and 15 which were generated from the content notes one sees a strong relation between Tables 14 and 18. Many of the words express a quality of care or imply a positive or pro-social value. Table 14 and 18 are both digests of larger bodies of information. Table 15 in contrast shares fewer words with Table 18 and is more specific in its information. This difference suggests that the inferences on which Table 15 are based are more subjective than those on which Table 14 is based.

Table 19 presents all words used three or more times in the reflection notes, exclusive of articles, prepositions, conjunctions, names, the verb *to be* and its conjugations, pronouns, numbers, and days of the week. The list of words was double-checked to ensure that upper- and lower-case versions of a word were tallied together and included if it appeared three or more times, in which case the lower-case version was added. Reading through these words and comparing them with Table 16 which was generated from the reflection notes, one sees a difference in quality akin to the difference noted between Tables 18 and 15. These differences again suggests that the inferences on which Table 16 are based are substantially subjective. Note further that Table 19 contains many more adjectives and adverbs than Table 18, as would be expected when comparing a reflection and inferences with content-based notes.

Table 19

Alphabetical List of Words Used Three or More Times in the Reflection Notes

Noun	Verb	Adjective	Adverb
abstraction	allows	able	again
anything	can	all	also
area	described	caring	better
attention	describing	comparative	deeply
care	do	each	inherently
communication	had	employed	may
concept	have	ethical	might
creativity	involves	lost	perhaps
details	Let	mathematical	so
ethic	need	mental	then
ethics	presented	new	there
framework	promote	no	very
health	promotes	other	yet
impression	resides	personal	
life	say	possible	
machine	see	potential	
mathematics	seen	related	
mode	talking	reproducible	
mood	think	role-based	
notes	work	sacred	
objects		some	
people		strengthened	
person		useful	
perspective		valid	
properties			
research			
researchers			
role			
scientists			
sense			
something			
spirit			
students			
study			
time			

Table 20

Alphabetical List of Words Used Three or More Times in the Mathematical Reflection Notes

Noun	Verb	Adjective	Adverb
animals	accorded	all	not
arguments	can	competing	once
body	extend	different	perhaps
criterion	have	ethical	really
ethics	may	extraterrestrial	then
example	need	fundamental	
framework	ought	interesting	
humans	trained	living	
Lie Algebras	treat	mathematical	
life		other	
machine		personal	
mathematics		same	
nature			
objects			
perspectives			
reflection			
rights			
self			
systems			

Table 20 presents all words used three or more times in the mathematical reflection notes, exclusive of articles, prepositions, conjunctions, names, the verb *to be*, pronouns, numbers, and days of the week. The list of words was double-checked to ensure that upper- and lower-case versions of a word that sum to three were included, in which case the lower-case version was added. The mood of the words in Table 20 is analytic and similar to the mood of the words in Table 17 and many words are shared by both. Likewise the mood of Table 20 is distinct from that of Tables 18-19, a difference that is consistent with the choice to focus specifically on mathematics for the reflective activity. One may conclude that the choice of mathematics was substantially subjective, while the

inferences drawn from that reflection were less subjective, that is, since many words are shared by both Tables 20 and 17.

The data and analysis from the Skype discussions will be addressed further in the discussion chapter which follows this one.

Questionnaire

Approximately 1550 questionnaire query emails were sent out from November 21 to 29, 2016. Responses were stored in the cloud and were not read until the conclusion of the structured reflection activities related to the Skype discussions described in the section above. On January 22, 2017, the researcher downloaded the questionnaire data from the cloud to a personal computer as a spreadsheet file. There were 29 participants and more than 300 substantive answers total. These were collected into a single document. A copy of this document was modified to protect respondent anonymity, that is, names and affiliations were not included, and affiliations in answers were redacted. A few orthographic errors were also corrected where it was clear that these were unintentional. This version was sent to the respondents for their interest. These questionnaire responses can be found in Appendix D.

Data Analysis

First I read through all the questions and their answers, in order but without reference to who had written what. Then I formulated a protocol for my next reading. This protocol formed the basis of a structured analysis of the answers. For each questionnaire answer, I composed:

- A brief restatement of the answer.
- An implication of the answer.

- An ethical perspective or several ethical perspectives that were evident in the answer, plus a reason for attributing those perspectives to the answer. If the answer context was ethics, I wrote the name of the ethical perspective in all capital letters.

In addition, I looked for:

- Statements recommending follow up research, for example, if the answer included a weblink or reference I was unfamiliar with.
- Statements that would be useful for policy recommendations.
- Statements that would be useful for teaching.

These statements were then copied to one of three separate documents for later use in devising the recommendations for policy makers and the lesson plans. I also made notes to myself of observations that occurred to me during the process of the analysis. The questionnaire answers were examined, and the analysis was generated during the period January 25 to February 1, 2017. The work was intensive and distraction was kept to a minimum to promote cohesion in how inferences were made. On February 6, 2017, these notes were revisited during the validation phase of the study. Six of the 390 responses that had been coded with an ethical perspective were reassigned from one ethical perspective (pragmatic) to perspective (utilitarian) after the validation process for clarity and consistency. The results and validation details below are of this revised version.

Results

Four categories of results became apparent as the work of analysis progressed:

1. Quantified frequency of occurrence of the various complementary ethical perspectives.

2. Findings related to the mode of analysis, and in particular related to the comparative ethical framework described in this manuscript.
3. Observations on the nature of science and the fields of astrobiology and machine life.
4. Suggestions related to ethics. Each of these four categories will be addressed below. Following these sections there will be a treatment exploring the validity and consistency of these results.

Occurrence of the complementary ethical perspectives. The frequency of ethical-perspective attributions from the questionnaire data are presented below. The questions are written out in Table 21 for reference. The incidence and frequency values are given in Tables 22 and 23, respectively. Where the context of the questionnaire answer is specifically ethics, the data are also listed in Tables 24 and 25 as an additional analysis.

Table 21

Questions from the Questionnaire

Number	Question
1	Please take a moment to reflect upon your professional life. What led you to the work that you do?
2	Please describe some questions that you are working on right now in your research and innovation. What research questions interest you?
3	Please describe a little about your philosophy towards your work. Is your approach scientific? What is a scientific approach to research and innovation?
4	Does any of your research use a definition of a living organism or a living system? If yes, please describe how a definition is used.
5	Are there any research areas that you imagine might benefit from a definition for living organism or system? If so, please describe how you imagine a definition might benefit the work.
6	Are there any research areas that you imagine might be hindered by having a definition of living organism or living system? If so, please describe how you imagine a definition might hinder progress.
7	What is your general opinion of ethical frameworks? Are they important? Are they valid?
8	In your field of research, what role do you see ethics playing, if any?
9	Do you have any recommendations regarding ethical frameworks as they relate to work fifty years from now? If so, please describe them.
10	So that your answers may be placed in context, you may enter your name and affiliation here, or just your name, or just your affiliation, as it suits you. You may also leave this question blank if you wish your answers to be anonymous.
11	What is your field of research or innovation?
12	Please take a moment and consider what you've written since the beginning of the questionnaire. What was your experience of taking this questionnaire? Did you find the experience useful? Please type any additional comments here.

Table 22

Instances of Ethical-Perspective Attributions in the Questionnaire Data

Question	n	K	C	Ae	E	-E	L	U	-U	P
1	73	7	7	24	9	-	2	3	-	21
2	47	-	-	28	8	-	1	1	-	9
3	49	2	-	26	2	-	-	3	1	15
4	48	3	-	25	4	-	-	-	-	16
5	41	2	1	27	1	-	1	2	-	7
6	39	3	-	26	1	-	-	1	1	7
7	35	9	5	1	4	1	-	5	-	10
8	34	4	10	5	1	-	1	5	-	8
9	24	2	6	7	1	1	2	3	-	2
12	4	3	-	1	-	-	-	-	-	-
Total	394	35	29	170	31	2	7	23	2	95

Note. n = number of attributions, K = Kantian, C = Care, Ae = Aesthetics, E = Evolutionary, -E = Opposed to Evolutionary Ethics, L = Land, U = Utilitarian, -U = Opposed to Utilitarian Ethics, P = Pragmatic. Dashes occur instead of zeros to increase readability.

Table 23

Frequency of Ethical-Perspective Attributions in the Questionnaire Data by Question

Question	n	K	C	Ae	E	-E	L	U	-U	P
1	73	0.10	0.10	0.33	0.12	-	0.03	0.04	-	0.29
2	47	-	-	0.60	0.17	-	0.02	0.02	-	0.19
3	49	0.04	-	0.53	0.04	-	-	0.06	0.02	0.31
4	48	0.06	-	0.52	0.08	-	-	-	-	0.33
5	41	0.05	0.02	0.66	0.02	-	0.02	0.05	-	0.17
6	39	0.08	-	0.67	0.03	-	-	0.03	0.03	0.18
7	35	0.26	0.14	0.03	0.11	0.03	-	0.14	-	0.29
8	34	0.12	0.29	0.15	0.03	-	0.03	0.15	-	0.24
9	24	0.08	0.25	0.29	0.04	0.04	0.08	0.13	-	0.08
12	4	0.75	-	0.25	-	-	-	-	-	-
Total	394	0.09	0.07	0.43	0.08	0.01	0.02	0.06	0.01	0.24

Note. n = number of attributions, K = Kantian, C = Care, Ae = Aesthetics, E = Evolutionary, -E = Opposed to Evolutionary Ethics, L = Land, U = Utilitarian, -U = Opposed to Utilitarian Ethics, P = Pragmatic. Dashes occur instead of zeros to increase readability.

The frequency of ethical perspectives is trimodal. In the first mode are aesthetics and pragmatism, with 170 and 95 attributions respectively. In the second mode are Kantian, evolutionary, care-based, and utilitarian ethics, with 35, 31, 29, and 23 attributions respectively. In the third mode are land-based ethics, with seven attributions, plus language that is opposed to evolutionary ethics or opposed to utilitarian ethics, with two attributions each.

In the first mode, aesthetics is associated with pragmatism as both are related to the work role: creating knowledge to share is an aesthetic undertaking, and many answers referenced this. Pragmatism can also be seen as a feature of the work of research. The practice of science involves a clear look at both the effects of phenomena and an interest in new solutions, new observations, or new information.

In the second mode, Kantian ethics may reflect a personal interest, an interest in self-reflection, an interest on how one's role is conceived, or a reference to transcendental ideas or other notions present in Kant's work. A reason for the frequency distribution of this ethical-perspective attribution is not obvious in this context as opposed to others. In contrast, knowledge of evolutionary ethics is clearly related to some of the work of the questionnaire participants. An ethics of care is related to a sense of care for vulnerable populations, and looks at whether the most vulnerable in a group are being cared for. Again, a reason for the abundance of care-based attributions is not obvious in this context as opposed to others. Utilitarian ethics are related to institutional stability and outcomes. There may be a relation between stability and the practice of research. Land-based ethics may be sparsely attributed in the questionnaire data for some reason that is also not obvious from the context.

Table 24

Instances of Ethical-Perspective Attributions in the Questionnaire Data Wherein the Context of the Attribution is Specifically Ethics

Question	n	K	C	Ae	E	-E	L	U	-U	P
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-
3	1	-	-	-	-	-	-	-	-	1
4	-	-	-	-	-	-	-	-	-	-
5	1	-	-	1	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	33	9	5	1	3	1	-	5	-	9
8	31	4	10	4	1	-	1	5	-	6
9	14	2	4	3	1	1	1	1	-	1
12	-	-	-	-	-	-	-	-	-	-
Total	80	15	19	9	5	2	2	11	-	17

Note. n = number of attributions, K = Kantian, C = Care, Ae = Aesthetics, E = Evolutionary, -E = Opposed to Evolutionary Ethics, L = Land, U = Utilitarian, -U = Opposed to Utilitarian Ethics, P = Pragmatic. Dashes occur instead of zeros to increase readability.

Table 25

Frequency of Ethical-Perspective Attributions in the Questionnaire Data by Question Wherein the Context of the Attribution is Specifically Ethics

Question	n	K	C	Ae	E	-E	L	U	-U	P
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-
3	1	-	-	-	-	-	-	-	-	1
4	-	-	-	-	-	-	-	-	-	-
5	1	-	-	1	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	33	0.27	0.15	0.03	0.09	0.03	-	0.15	-	0.27
8	31	0.13	0.32	0.13	0.03	-	0.03	0.16	-	0.19
9	14	0.14	0.29	0.21	0.07	0.07	0.07	0.07	-	0.07
12	-	-	-	-	-	-	-	-	-	-
Total	80	0.19	0.24	0.11	0.06	0.03	0.03	0.14	-	0.21

Note. n = number of attributions, K = Kantian, C = Care, Ae = Aesthetics, E = Evolutionary, -E = Opposed to Evolutionary Ethics, L = Land, U = Utilitarian, -U = Opposed to Utilitarian Ethics, P = Pragmatic. Dashes occur instead of zeros to increase readability.

Finally, note that respondents decried two of the seven ethical perspectives. Evolutionary ethics were rejected twice, each time within a context of ethics. Utilitarianism was rejected twice, neither time within an explicit context of ethics. It is not clear why these two are disavowed specifically in this setting, though both Social Darwinism and utilitarianism have been used as justifications for large scale violence.

Note that when the context of the questionnaire answer is specifically ethics, the distributions are also trimodal. See Tables 24 and 25. In the first mode are the ethics of care, pragmatism, and Kantian ethics, with 19, 17, and 15 attributions respectively. In the second mode are utilitarian ethics and aesthetics, with 11 and 9 attributions respectively. In the third mode are evolutionary and land-based ethics, with five and two attributions respectively, plus language that is opposed to evolutionary ethics, with two attributions. In short, when the context of the answer is specifically ethics, the ethics of care and Kantian ethics both jump up to the first mode, while aesthetics drops down to the second mode; evolutionary ethics likewise falls down to the third mode. Land-based ethics and language opposed to evolutionary ethics remain in the third mode, while language opposed to utilitarian ethics is absent. The distance between the three modes is smaller here than in the more general context.

The findings of this analysis are summarized in Table 26. Except for the questions asking for name and affiliation (Question 10), or field of research (Question 11), all answers received 28 or 29 responses. Data not summing to this reflect answers that gave no usable information, for example, "sorry" or "no" or some other text wherein an attribution to one of these seven ethical perspectives was not clear.

Table 26

Findings of the Frequency Analysis of the Questionnaire Data

Findings of the Frequency Analysis of the Questionnaire Data
Aesthetic and pragmatic attributions were the most common in general answers by far. One may infer that a majority of these researchers take a pragmatic approach and are highly involved in culturally-mediated activity.
When asked specifically about ethics, respondents used language that referred to pragmatism, the ethics of care, or personal (Kantian) ethics most often. The ethics of care and personal (Kantian) ethics come to mind in the context of ethics specifically more than when the subject is not turned to ethics.
A land-based ethics is not evident in the great majority of responses.
Evolutionary ethics and utilitarianism were specifically opposed in some responses.

Refining the ethical framework. Kantian ethics were assigned for three complementary features present in some responses. First, Kantian ethics focus on internal or personal assessment, namely, assessing whether one's actions are congruent with a categorical imperative is an internal process. Thus, answers that relied on personal or internal language were scored as Kantian. Second, Kantian ethics are role-based in that a categorical imperative assesses how well one inhabits a role. Thus, answers that suggested a strong consideration of one's role were scored as Kantian. Third, Kant's philosophy defines a novel, transcendental approach to thinking about analysis. It also strongly focuses on a few concepts, for example, duty, paradox (which appears in Kant's work with antinomies) and other terms. Thus, answers that suggest reaching beyond limits or objects, or other strongly Kantian concepts were scored as Kantian. In short, Kantian ethics for the purpose of this exercise could include personal, role-based, or Kantian language. Yet there were many answers that included reference to role, and clearly not all of these responses were congruent with a Kantian perspective.

Many answers were simply commenting on inhabiting the role of scientist, and describing the work done as a scientist or researcher. I determined aesthetics was an appropriate label for these responses. As a category, aesthetics had been placed among the seven complementary ethical perspectives to account for the myriad religious systems that favor ritual and cultural practices. The concrete rubric for these systems is whether ritual practices are done well. The same rubric is readily apparent in scientific work.

In general, aesthetics refers both (a) to the creation of cultural products, and also (b) to perceptions and how products or information are perceived. This dual meaning is how aesthetics is applied to the field of the arts, referring both to cultural objects and also to the process of perception. In the questionnaire analysis, the assignment of aesthetics was made in these two categories as well. First, aesthetics was assigned when the emphasis of the language was in creating new knowledge to share. Second, aesthetics was assigned when answers referred to questions of how information would be perceived. For nearly all of the questions related to research and work, answers were scored as making reference to aesthetics. As a system, aesthetics resides in cultures and subcultures—it helps to define the subculture of science research.

Note that I did not include logical positivism in the set of seven ethical perspectives studied, yet a respondent writes "trust in logically consistent solutions" as their work motivation, which I score as aesthetics, that is, an interest in a feature of the artifacts of science. Perhaps this is unfair, and yet it is consistent in that all such references can be seen as features of scientific knowledge. In contrast, pragmatism is adopted in a wide range of fields. It is positivism's converse. Pragmatism posits the existence of no logical objects. This asymmetry, of subsuming positivism while

embracing pragmatism, is not fatal, for the reason given above. Logical positivism can be seen as an aesthetic position in that it describes a mode of perception which mediates how scientific knowledge is produced. Pragmatism has a larger scope.

Pragmatism is inherently focused on: (a) developing new methods, (b) aggregate effects, (c) what is practical, and (d) contextualization that can change with time. A useful example to keep in mind as a means of understanding the epistemological basis of the pragmatic perspective is this maxim of Charles Sanders Pierce:

Consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object. (Pierce, 1878, p. 6)

Most examples of pragmatism in the questionnaire analysis may be related to adopting a scientific perspective. In general, very short answers were also marked as pragmatic if they seemed clipped in tone, indicating a measured approach to language.

Utilitarianism was assigned based on three ideas: (a) that there are no limits to behavior so long as a greater good is the goal, (b) a balance sheet approach to economic and other issues, and (c) applied ethics. "Choosing to be unethical" was assigned as evidence of a utilitarian approach due to its focus on outcomes without reference to any other feature, and also that perspective having been championed by Bentham and other proponents. In the questionnaire analysis, the realm of applied ethics was also taken as utilitarian—since it forms a static basis for decisions of one outcome over another.

Note that there were six instances wherein the coding was changed during the validation stage, reassigning answers from pragmatism to utilitarianism. Each of these cases included reference to either no limits (a) or balance sheet (b) or applied ethics (c). The fault had been in the application of the rubric by the author. Utilitarianism aims at

stability and producing the greatest good, while pragmatism aims at progress and developing new things—whether new classifications or new technology. Each is concerned with the use of objects and actions and not the objects and actions themselves.

Of the seven ethical perspectives presented (Kantian, care, aesthetics, evolutionary, land, utilitarian, pragmatic), the first three listed represent a single category, i.e., Kantian ethics are personal, the ethics of care are social, and aesthetics are cultural. Evolutionary and land ethics both relate to the environment; utilitarian and pragmatic ethics each are quantitative. Within the context of the questionnaire, and in addition to references to evolution, biological experiment, and systems, I took the notion that human life is the most important consideration in ethical dilemmas as an example of adherence to evolutionary ethics. It is the notion that human survival is at stake, and takes recourse in the idea of a hierarchy of organism worth (or of group worth), which itself is a survival strategy. Answers expressing this view, for example "other living beings which have been assigned by humans to possess specific rights, e.g., animals," were coded by the author with the tag *evolutionary ethics*. Thus evolutionary and land ethics can be seen as adversarial perspectives of the same category, pitting human survival against the survival of the land or the ecosystem.

The findings of this section are summarized in Table 27. The process of developing these findings was a combination of induction during the coding phase and revision during the validation phase.

Table 27

Summary of Findings Related to the Comparative Ethical Framework Presented in this Project

Findings Related to the Comparative Ethical Framework
Kantian ethics may include elements of personal, role-based, or transcendental language.
Aesthetics is a feature of creating new knowledge to share and of perception. What scientists do is governed by aesthetics.
Logical positivism can be seen as an aesthetic position in that it describes a mode of perception.
That human life is the most important consideration in ethical dilemmas is an example of evolutionary ethics.
Pragmatism focuses on developing new methods, and outward effects, i.e., what is practical.
Applied ethics can be taken as a utilitarian perspective since it forms a static basis for decisions based on outward effects.
Evolutionary and land ethics can be seen as competing environmental perspectives, pitting human survival against the survival of the land or the ecosystem.

Science, astrobiology, and machine life. What follows are answers or parts of answers from the questionnaire that seemed notable related to science, astrobiology, and machine life. These are meant to be an exploratory exercise for the reader. A very brief treatment follows. They are divided into categories.

1. Career interest.

I became interested in philosophy at some point in high school. After reading a bit here and there I came to the conclusion that without understanding space and time I won't get further. So I studied physics. I studied some AI, robotics, and neuroscience on the side and at some point realized that I won't make it in string theory. So I asked myself what would I do if I already knew the end result of string theory, the grand unified theory. I thought I would want to find out what life is. So that is what I do now.

When I was taking second-year biology in high school, I collected algae (pond scum) from a stream in Pennsylvania and looked at it under a microscope. It turned out to be *Spirogyra*, and it was quite awesome. I decided to be a biologist. The next year, I had a wonderful chemistry teacher who told me that biochemistry was the hot new field. Her advice sounded good to me and I decided to be a biochemist. Fast-forward 46 years, to March 2007. I'm looking into the dissecting

microscope in my home. I'm putting water on a piece of mica that my brother and I collected on a hike several months earlier. As I watch the water seep between the sheets of mica, it occurs to me: this might be a great place for the origin of life!

It was my original intention to become a medical doctor, and I prepared for such throughout high school and college. During my senior year of college, I decided that a career in medicine wasn't for me, so I instead entered grad school to study astrobiology and the origin of life; subjects which piqued my interest at the time (and still do).

I have always been interested in what makes life different than non-life. It was always the biggest question in my mind and much more interesting than any of the other subjects/questions. Growing up, I always became bored with everything very quickly. Physics and science was the only think that remained interesting after many hours of exploration.

2. What is science?

I ask many questions, and when there are no answers, it generally means that I am examining an area between disciplines. So then I try to answer the questions myself.

My philosophy is that research should be aimed at answering new questions for which answers are not presently available—trying to understand how life works in places where things are so extreme or different that we don't understand now. Also, keeping one's eyes open for things that don't fit the present paradigm(s), which of course, are not always correct.

Lately, I've been saying that my philosophy is inspired by George Box: All models are wrong.

I do not see my work as an effort to understand the inner working of the universe. I do, however, see it as an effort to predict from what has already happened what is likely to happen next. I do not believe that at some point in my work I will suddenly realize that the future is at last entirely known. I do, however, believe that for the foreseeable future I will be able to do a better and better job of predicting what is going to happen next.

My approach is scientific in the sense that the processes in my simulations are physically validated. The motivation behind the research is backed more by curiosity than pure reasoning. Of course, the motivation behind any research area is backed by axiomatic boundary conditions that justify one area of focus over another.

Definitions are more helpful in codifying what we understand than what we want to understand. They rigidize boundaries. They are more helpful in research politics than in research itself.

I don't think we can do without definitions, or at least partial definitions, but we must be very careful as is I believe very widely appreciated among astrobiologists who are developing creative ways of looking for they know not what, a rather difficult task when you think about it.

3. Consciousness.

The universe can be considered as an exploration of methods of maintaining continuity (survival). Life consists of forms or systems which use positive feedback for survival. It seems likely that the only way that the universe can initiate these is through biochemistry. But when biology develops intelligence (nervous systems, motor organs and sensing) that intelligence can develop physical intelligent life. Because these can (and likely have already) operate in a much wider range of physical conditions than biological life, and can "hibernate" for thousands of years, they will be able to explore the universe and find better survival habitats as well as explore the full range of scientific questions, again so as to improve their survival continuity.

A colleague once challenged my evolutionary definition of life by proposing to contemplate an artifact that does not reproduce or evolve, but which has a convincingly human-like mind. He had me.

4. Agency in artificial intelligence (AI) systems.

I want to find out how a dynamical system can contain something that justifiably can be called an agent. I.e. a thing that is individualized, can "act", and has some kind of goal-directedness. Since for a dynamical system the dynamical law determines everything that is going on within it, it seems paradoxical that within such a system something could exist that can perform its own actions and has its own goals. I try to formally define notions of individuals, actions, and goal-directedness which "make sense" and can occur within dynamical systems.

How can machine learning systems be made robust to "unknown unknowns"; to unanticipated aspects of the world?

I work in robotics as well, but nobody really cares about living vs. non-living, they care about degrees of autonomy and intelligence.

5. Mineralogy.

I'm working on the idea the the spaces between mica sheets are an excellent place for the origins of life. My latest insight[?] is that organelles without membranes are a more likely place for life's origins than fragile membrane-enclosed organelles. My work is all 'armchair' or 'theoretical', except for occasional kitchen-counter experiments with mica.

Mica sheets can form a substrate that is (1) similar to an enzyme in providing open-and-shut motions and transition metal ions and (2) a unique environment—that is, the transition to life is not a clear demarcation

6. Thermodynamics.

Can thermodynamics help predict relative abundances of various biomolecules synthesized by life? Can we characterize the balance of "function" and "cost" of biomolecules depending on the environment inhabited by an organism?

7. Interstellar medium.

I am exploring the origin of the interstellar medium.

Is there a direct connection between the chemistry in cold dark regions of space and life on Earth?

8. Genetics.

Were the first forms of life chemically similar to modern-day life, in terms of being constructed from amino acids and/or nucleotides, or should we expect them to have been based on a different chemistry, with the modern biochemistry arising later as the result of evolution?

9. Evolution.

Is there a "Moore's law" for evolution? I.e. under appropriate circumstances, can a biological species accumulate adaptations at an exponentially accelerating rate?

I am also interested in the processes of evolution, especially those often categorized as "the extended synthesis" and how they relate to humans - thus questions like how do cultural differences and physical phenotypic plasticity or niche construction relate in the human (and other cultural animals)?

10. Development.

Is embryogenesis a branching, goal seeking process?

11. Exoplanetary atmospheres.

How would we recognize the remotely-detectable signs of life on a habitable exoplanet? What can we do to mitigate against the potential for "false positive" detections? How common are planetary biospheres like Earth, and what is their distribution in the solar neighborhood? As currently our only example of a habitable and inhabited planets, how has Earth's spectral character evolved with geologic time? How good of an analogy does Earth provide in the search for life outside the solar system? What can prospective modeling of exoplanet

atmosphere do for setting the instrument requirements for robustly detecting life outside the solar system?

12. Chirality.

How do you go from an racemic mixture of chemicals (amino acids or sugars) to the homochiral systems employed by biology?

13. Living in space.

I am also interested in the development of sustainable spaceflight having developed numerous designs for spacecraft and recently [a] design for handling and harvesting resources from asteroids.

14. Nature of life.

I work more in the "mind" domain than in the "life" domain. However, when developing general theories of mind, they tend to converge with theories of life (i.e., both focus on system(s) relating meaningfully with their environment). In a sense, from a pure systems-theoretical standpoint -my own standpoint- both kind of theories -mind, life- shall be instantiations of a more general model of autonomous systems in changing environments (informational for mind, chemical for life).

Have a reductionist approach that boils life down to the concept of memory (either DNA/RNA or computer) when life is in suspended animation.

Addy Pross' *What Is Life?* is about chemical systems (i.e., dynamic kinetic systems) wherein the fittest chemistries win akin to ecological systems wherein the fittest populations win.

My general assumption is: If it can attack me, it's alive. That therefore includes robots.

I think in this moment, I would define life as something that is capable of subjective computation, which is computation based on partitioning a system. Non-life computes much like a modern computer does, but life computes in a much different way. I think that life might use its own data and the data of different partitions of different systems to compute.

Some of the computational models I employ use models for the inputs and outputs of living systems, although for the most part those living systems are not modeled themselves. In this case, the definition of a living system is a process that takes inputs or produces outputs that are not from other geochemical, atmospheric or other planetary processes.

I also appreciate that one can't get very far in proposing a model for the origins of life without some kind of definition. The same, I presume, would apply to artificial life research, to virology, to the study of active matter. But I don't think we need a full-orbed definition to get on with the work, for it might be perfectly sufficient to ask about the minimal requirements for the assembly of long peptide chains, recognizing that this is a central aspect of the workings of life as we know it.

Exceptions may arise. Jumpy genes that are carried by viruses to hosts and back and forth are effectively organisms with their own evolutionary interests.

The origin of life field has not benefited much from efforts to define a living organism. "Minimal viable cell" and other concepts have been interesting intellectual exercises but are difficult to test and don't give us much guidance to experiment on much simpler systems which would have had to start up to lead to life.

Most striking in the excerpts above is their variety and passion. Creativity and discipline are each evident in abundance. Two observations based on these follow. The above are obviously rich enough for much more analysis, but the process will be restricted to these two, as they interact with the concept of comparative ethics.

First, pragmatism in the language of the 300+ questionnaire answers is prevalent, and much more prevalent than utilitarianism, which is the more broadly reductionist of the two perspectives. I suggest, based on the curiosity and passion present in the above quotations, that the dissatisfaction with what is called "reductionist science" is perhaps misplaced. A distinction between pragmatism and utilitarianism has not been made yet in the public discourse and would be useful.

Second, note that autonomy is essential in a Kantian framework. Autonomy is also one of the features of robotics and artificial intelligence (AI) that is important. Autonomy involves a good deal of role-based contemplation. How working on autonomous systems affects the researcher's ethical perspective is an interesting issue. There is perhaps room for a follow-up study at a later date to explore how working in

machine agency influences one's experience of role-based reflection. Note that there will be additional analysis of answers from the questionnaire presented in the recommendations for policy makers and lesson plan sections.

Suggested ethics. What follows are answers or parts of answers from the questionnaire that seemed notable related to ethics. As with the above section, these are meant as an exploratory exercise for the reader.

The importance and validity of any particular ethical framework are only revealed over the course of many generations. What I have in mind in saying that is this. Imagine two separate societies A and B with two distinct ethical frameworks a and b. Allow these societies to develop over the course of many generations all the while adhering to their respective ethical frameworks. It would seem to me reasonable to judge the importance or validity of a versus b according to the wealth of A versus B. I think in this sense, it is pretty easy to conclude, for example, that the ethical framework of Nazi Germany (if that concept is not an oxymoron) is neither important nor valid. But beyond such clear cases of low importance and low validity, I would be unwilling to go.

If we want machines to have subjective experience, then we need to understand how subjective experience arises in biological systems, currently the only examples of consciousness that we have. But do we want machines to have these properties? <- this is the ethical problem.

Ethics operate at many levels. The first is personal research, where one must be able to fully disclose results so that biased reports of one's work are avoided. At a larger level, one wants to avoid detrimental environmental effects that might result from one's research.

Yes: the worldwide ban on human embryo experimentation may be severely limiting our ability to understand how human embryos form. This has the ethical consequence of hindering research on how to prevent birth defects, for example. Of course, it is tied up with the theological notions of when a soul enters an embryo, and rights of the not yet born. As the science of souls is pretty primitive, it's hard to be definitive.

In a deep sense, AI software is not correct unless it correctly obeys ethical frameworks. A major area of impact in AI is that like any new technology it has the potential to eliminate many jobs and create new jobs. This displacement in employment appears to be having a huge impact on human society. AI researchers have a responsibility to work with others (e.g., economists and sociologists) to understand and mitigate these impacts.

Ethical frameworks must evolve as society changes. My only recommendation is that we should always be teaching university level courses that introduce students to the kinds of ethical decisions they will need to make as they go through their lives and careers.

Whenever computer scientists attempt to replicate human behavior, we need to evaluate our systems. This leads us to ask awkward questions such as "How accurate are human physicians?" "How just are human judges?", "How well do people drive cars?" In order to evaluate AI systems, we will need to ask "How ethically do humans behave?" and this will lead to deeper and more precise formulation of ethical frameworks. I believe fifty years from now, this will result in a much deeper understanding of ethical frameworks that ultimately will lead to improved criminal justice and government regulations.

The ethics of CRISPR must be worked on, but after all, in another sense it largely just does much more effectively things that have been approached ethically already.

Any moral or ethical system based on Darwinian principles is guaranteed to be a bad ethical system. The Darwinian process can not produce ethical behavior above the level of the highest unit of selection. In humans that is the group. Humans naturally tend to produce ethical behavior within the group they identify with, and horrifically unethical behavior toward other groups of the same category. This is our innate psychology, which we must overcome or perish.

As with the questionnaire excerpts in the previous section, a most striking finding related to the excerpts above is their variety and passion. Creativity, self-reflection, and discipline are each evident in abundance. Observations based on these follow later in the chapter in the section that gives recommendations for policy makers. The section immediately below addresses issues of validation and consistency. Recommendations for policy makers follow that.

Validation of the Questionnaire Data Analysis

Validation was undertaken to assess coherence and consistency for the four sections above.

Occurrence of the complementary ethical perspectives. A validation strategy was undertaken to assess the assignment each ethical perspective to questionnaire answers as follows. The ethical perspectives and rationales assigned to each answer were copied from the notes taken and sorted so that the rationales of each ethical-perspective assignment were placed together. Likewise, the same was done with the two instances wherein answers suggested negating a perspective, namely, specifically not-ecological or not-utilitarian. These nine lists were then checked for clarity and consistency. The results of this process are given in Tables 28-36.

1. Kantian ethics. See Table 28. The rationales given for assigning Kantian ethics fall into six categories: role (13), personal (8), transcendental (7), categorical (3), duty (2), and antinomies (2). Two out of the 35 reasons given for attributing Kantian ethics to the language of the questionnaire answers were somewhat questionable: "makes distinctions clearly and in context" and "refers to an idealistic approach." It was possible to include each of these into a category, and they were given the status of being somewhat questionable and not invalid outright. The rationales for this category seem to be highly consistent with the intent of the researcher.

Table 28

Validation of the Rationale for Assigning Kantian Ethics to Questionnaire Data

Rationale for Kantian Ethics Attribution	Idea	Valid?
Acting in a role that is with good faith	Role	Yes
Aware of role and duty towards it	Role	Yes
Aware of role as a scientist	Role	Yes
Awareness of their own role	Role	Yes
Based on what's right in each situation	Categorical	Yes
Comfortable with paradox	Antinomies	Yes
Concerned that transcendentalism ought to be more widespread	Transcendental	Yes
Concerned with researchers and robots inhabiting the role appropriately	Role	Yes
Duties of the role	Role	Yes
Ethics are transcendent and exist in the mind	Transcendental	Yes
Explicit sense of role	Role	Yes
Finds the limit of what is known as in an antinomy	Antinomies	Yes
Focus on professionalism and role in choices	Role	Yes
Focused on role as scientist	Role	Yes
Focused on the subjective	Personal	Yes
Focused on transcendental principles behind both life and mind	Transcendental	Yes
Humans and some animals are spiritual beings and not just physical mechanisms	Personal	Yes
Implicit sense of duty to pursue most interesting	Duty	Yes
Intuition forms the basis for our appropriate behavior	Personal	Yes
Looking to protect role as a scientist	Role	Yes
Makes distinctions clearly and in context	Categorical	?
Mentions transcendental concepts	Transcendental	Yes
Not following the professional role	Role	Yes
Personal duty	Personal	Yes
Professional role (x2)	Role (x2)	Yes
Public duty of scientists	Duty	Yes
Refers to an idealistic approach	Transcendental	?
Refers to transcendental ideas	Transcendental	Yes
Scientist is an instrument of science	Categorical	Yes
Self-reflecting (x3)	Personal (x3)	Yes
Subjective	Personal	Yes
Transcendental thought experiment	Transcendental	Yes

2. *Ethics of care*. See Table 29. The rationales given for assigning ethics of care fall into three categories: care (27), medical (1), and community (1). One out of the 29 reasons given for attributing ethics of care to the language of the questionnaire answers was somewhat questionable: "concerned by the vulnerability of research." It was possible to include this into a category, and yet it is unclear whether caring for research and caring for people or other vulnerable organisms are equivalent. This rationale was given the status of somewhat questionable and not invalid outright. The rationales for this category seem to be highly consistent with the researcher's intent.

3. *Aesthetics*. See Table 30. The rationales given for assigning aesthetics fall into two categories: artifact (164) and perception (6). One out of the 170 reasons given for attributing aesthetics to the language of the questionnaire answers was somewhat questionable: "important as scientist." It was unclear whether the reference is to role or to product. This rationale was given the status of somewhat questionable and not invalid outright. The rationales for this category seem to be highly consistent with the intent of the researcher.

Table 29

Validation of the Rationale for Assigning an Ethics of Care to Questionnaire Data

Rationale for Ethics of Care Attribution	Idea	Valid?
Care for the vulnerable other groups	Care	Yes
Care for vulnerable on other planets	Care	Yes
Caring for the planet	Care	Yes
Caring for vulnerable in war and workforce	Care	Yes
Clinical (medical) focus	Medical	Yes
Concerned by the vulnerability of research	Care	?
Concerned for vulnerable populations	Care	Yes
Concerned with technological impact on vulnerable populations	Care	Yes
Danger to populations	Care	Yes
Ethics applies to those who are vulnerable	Care	Yes
Focus on helping others	Care	Yes
Focuses on vulnerable populations	Care	Yes
Implicit idea of care for a vulnerable self in the story	Care	Yes
Mentions social groups and help	Care	Yes
Most vulnerable during clinical trials	Care	Yes
Personal ought not overtake others' needs	Care	Yes
Proposing assistance for students	Care	Yes
Protection for the vulnerable	Care	Yes
Risk to vulnerable populations	Care	Yes
Role of empathy in decision-making	Care	Yes
Social benefit	Care	Yes
The future is a vulnerable population as they cannot weigh in at present	Care	Yes
Unintended consequences for those vulnerable	Care	Yes
Vulnerable (exoplanetary) populations may need protection	Care	Yes
Vulnerable populations	Care	Yes
Vulnerable populations + living machines as potential vulnerable populations (x2)	Care (x2)	Yes
Vulnerable populations of humans and animals in research	Care	Yes
Willing to work within a community framework as evidenced by her respectful attitude towards schooling	Community	Yes

Table 30

Validation of the Rationale for Assigning Aesthetics to Questionnaire Data

Rationale for Aesthetics Attribution	Idea	Valid?
A cultural product that can be developed	Artifact	Yes
Adopts a general notion from movies a cultural artifact	Artifact	Yes
Argument based on immediacy and beauty	Perception	Yes
Based on how the research will be perceived	Perception	Yes
Careful with creating new knowledge to share	Artifact	Yes
Clear understanding of creating knowledge to share	Artifact	Yes
Communicating scientific knowledge	Perception	Yes
Concerned with a knowledge product	Artifact	Yes
Concerned with creating new knowledge to share	Artifact	Yes
Concerned with how new knowledge is created to share	Artifact	Yes
Concerned with principles of creating knowledge for sharing	Artifact	Yes
Concerned with the artifacts of creating knowledge to share	Artifact	Yes
Concerned with the products of culture	Artifact	Yes
Considering how new knowledge is created to share (x3)	Artifact (x3)	Yes
Creates knowledge to share	Artifact	Yes
Creating knowledge and artifacts to share	Artifact	Yes
Creating knowledge to share (x54)	Artifact (x54)	Yes
Creating knowledge to share via principles of logic	Artifact	Yes
Creating knowledge to share via the scientific method	Artifact	Yes
Creating new knowledge to share (x4)	Artifact (x4)	Yes
Creating software to share	Artifact	Yes
Cultural-artifact focus in computers and knowledge	Artifact	Yes
Describes process of creating knowledge to share (x2)	Artifact (x2)	Yes
Describes the process of creating knowledge to share (x2)	Artifact (x2)	Yes
Describes the process of knowledge creation	Artifact	Yes
Describing the process of creating knowledge to share	Artifact	Yes
Devising knowledge to share	Artifact	Yes
Engaged in knowledge creation	Artifact	Yes
Ethical frameworks are cultural objects	Artifact	Yes
Ethics are cultural products that evolve over time	Artifact	Yes
Ethics ought to be integrated into the process of creating knowledge to share	Artifact	Yes
Focus on creating knowledge to share (x3)	Artifact (x3)	Yes
Focus on feature of scientific knowledge	Artifact	Yes
Focus on machines a cultural artifact	Artifact	Yes
Focus on science as creating knowledge to share	Artifact	Yes
Focus on the cultural role of ethics	Artifact	Yes
Focused on creating knowledge to share (x5)	Artifact (x5)	Yes

Rationale for Aesthetics Attribution	Idea	Valid?
Focused on creating knowledge to share + imagination	Artifact	Yes
Focused on knowledge creation	Artifact	Yes
Focused on the passion in creating knowledge to share	Artifact	Yes
Follows personal interest for creating knowledge to share	Artifact	Yes
Important as scientist	Artifact	?
In the process of constructing knowledge to share	Artifact	Yes
Includes science as a cultural pursuit	Artifact	Yes
Interest in knowledge	Artifact	Yes
Interest in the knowledge and understanding	Artifact	Yes
Interested in creating cultural artifacts	Artifact	Yes
Interested in the ideas behind things in order to create knowledge	Artifact	Yes
Involved in creating knowledge	Artifact	Yes
Involved in creating knowledge to share (x25)	Artifact (x25)	Yes
Involved in creating new knowledge to share (x13)	Artifact (x13)	Yes
Involved in the creation of knowledge to share	Artifact	Yes
Looking at how work is perceived	Perception	Yes
Perception of a threat or moral or religious questions	Perception	Yes
Perception of cultural harm less important but perception of minor opportunity cost is confirming	Perception	Yes
Practical consideration of how cultural product is funded and produced	Artifact	Yes
Principles for creating new knowledge to share	Artifact	Yes
Process for creating knowledge to share	Artifact	Yes
Processes for creating new knowledge to share	Artifact	Yes
Reference to cultural artifacts	Artifact	Yes
Refers to unwritten rules for creating knowledge	Artifact	Yes
Related to creating new knowledge to share (x3)	Artifact (x3)	Yes
Taking a view of scientific practice that is about cultural form	Artifact	Yes
Work as creating knowledge to share	Artifact	Yes
Works in creating knowledge to share in many related fields + culture	Artifact	Yes
Writes grants to creating knowledge to share	Artifact	Yes

4. *Evolutionary ethics*. See Table 31. The rationales given for assigning evolutionary ethics fall into four categories: evolution (21), system (6), homocentric (3), and experiment (1). None of the 31 reasons given for attributing evolutionary ethics to the language of the questionnaire answers were deemed questionable. The rationales for this category seem to be highly consistent with the intent of the researcher.

Table 31

Validation of the Rationale for Assigning Evolutionary Ethics to Questionnaire Data

Rationale for Evolutionary Ethics Attribution	Idea	Valid?
Clearly a science focus and evolutionary ideas are based therein	Evolution	Yes
Curiosity about decision-making processes of people	System	Yes
Curiosity about emergence in systems	System	Yes
Describes a cooperative mode of evolution	Evolution	Yes
Experimental results	Experiment	Yes
Explicit interest in evolutionary processes	Evolution	Yes
Explicitly that ethics is part of evolution	Evolution	Yes
Expressed interest in evolution	Evolution	Yes
Expressed interest in evolutionary processes' influence on human culture	Evolution	Yes
Focus on features of dynamical systems	System	Yes
Focus on the context ie space and time	System	Yes
Focus on the universe as maintaining continuity or survival	Evolution	Yes
Focuses on evolutionary fitness	Evolution	Yes
Human needs seen as important over other needs	Homocentric	Yes
Importance of human life over others	Homocentric	Yes
Interest in the topic of evolution inferred from training	Evolution	Yes
Involved in the principles behind life and aware of differences in environment and their effects	Evolution	Yes
Life on mars implies interest in evolution	Evolution	Yes
Mechanisms of organism development	Evolution	Yes
Mentions interest in evolution	Evolution	Yes
Placing humans and certain animals at the top	Homocentric	Yes
Refers explicitly to physical life finding its own ethics	Evolution	Yes
Refers to a potential evolutionary pathway in viruses	Evolution	Yes
Studies environmental conditions for extremophiles	Evolution	Yes
Studies evolution	Evolution	Yes
Studies features of darwinian evolution	Evolution	Yes
Studies issues surrounding living species and sustainability	System	Yes
Studies principles of evolution	Evolution	Yes
Studying the processes of ecosystem stasis or change	System	Yes
Trained in and works in evolution	Evolution	Yes
Uses evolutionary terms	Evolution	Yes

Table 32

Validation of the Rationale for Assigning Not-Evolutionary-Ethics to Questionnaire Data

Rationale for Attribution Opposing Evolutionary Ethics	Idea	Valid?
Explicitly states that nature is not ethical	Evolution	Yes
Opposed to darwinian principles in ethics	Evolution	Yes

Table 33

Validation of the Rationale for Assigning Land-Based Ethics to Questionnaire Data

Rationale for Land-Based Ethics Attribution	Idea	Valid?
Appreciation for the natural world	Nature	Yes
Avoid impacting environment	Conservation	Yes
Examples cited were environmental and systemic	Conservation	Yes
Outdoor and hiking experience	Nature	Yes
Poetic language "distant world"	Nature	Yes
Protection for the environment	Conservation	Yes
Reference to environment	Conservation	Yes

5. *Opposed to evolutionary ethics.* See Table 32. The rationales given for assigning opposition to evolutionary ethics fall into one category: evolution (2). Neither of the two reasons given for attributing opposition to evolutionary ethics to the language of the questionnaire answers was deemed questionable. The rationales for this category seem to be highly consistent with the intent of the researcher.

6. *Land-based ethics.* See Table 33. The rationales given for assigning land-based ethics fall into two categories: conservation (4) and nature (3). None out of the seven reasons given for attributing land-based ethics to the language of the questionnaire answers were deemed questionable. The rationales for this category seem to be highly consistent with the intent of the researcher.

Table 34

Validation of the Rationale for Assigning Utilitarian Ethics to Questionnaire Data

Rationale for Utilitarian Ethics Attribution	Idea	Valid?
Affect the wealth of nations	Balance sheet	Yes
All is fair no limits	No limits	Yes
Animal research for greater human good	No limits	Yes
Applied ethics	Applied ethics	Yes
Choosing to be unethical	No limits	Yes
Cost-sheet analysis	Balance sheet	Yes
Distinctions of work and hobby imply utilitarian framework	?	?
Ethical constraints get in the way of goals	No limits	Yes
Explicitly agrees with Bentham	No limits	Yes
Focused on financial application of idea	Balance sheet	Yes
In favor of a regulatory system of ethics	Applied ethics	Yes
Includes funding in analysis of what is studied	Balance sheet	Yes
Look at the policy difficulties	Applied ethics	Yes
Looking at applied ethics related to human and animal research	Applied ethics	Yes
Meaning abstracted into statistical truth	Balance sheet	Yes
Operational in reaching what is considered beneficial and avoiding what is detrimental	Balance sheet	Yes
Sees no role for ethics except for utility or interest	No limits	Yes
Sees one type of field valued over another	Balance sheet	Yes
Sees otherworldly life as a simple object of study	No limits	Yes
Sense of people as means to an end	No limits	Yes
Separate functionality from its context of production	No limits	Yes
Using computers and life as a tool	Balance sheet	Yes
Utility of choices	Balance sheet	Yes

Note. Bold entries are those that had been previously assigned to pragmatism.

Table 35

Validation of the Rationale for Assigning Not-Utilitarian-Ethics to Questionnaire Data

Rationale for Attribution Opposing Utilitarian Ethics	Idea	Valid?
Does not see a single reductive aim	No balance sheet	Yes
Wants to protect knowledge	Limits	Yes

7. *Utilitarian ethics*. See Table 34. The rationales given for assigning utilitarian ethics fall into three categories: no limits (9), balance sheet (9), and applied ethics (4), plus one unassigned. One out of the 23 reasons given for attributing utilitarian ethics to the language of the questionnaire answers was unclear: "distinctions of work and hobby imply utilitarian framework." It was not possible to include this into a category. The rationales for this category seem to be highly consistent with the intent of the researcher. The rubric developed allowed for six codes to be switched from pragmatism to utilitarianism. These six are listed in bold in Table 34.

8. *Opposed to utilitarian ethics*. See Table 35. The rationales given for assigning opposition to utilitarian ethics fall into two categories: limits (1) and no balance sheet (1). Neither of the two reasons given for attributing opposition to utilitarian ethics to the language of the questionnaire answers was deemed questionable. The rationales for this category seem to be highly consistent with the intent of the researcher.

9. *Pragmatic ethics*. See Table 36. The rationales given for assigning pragmatic ethics fall into seven categories: practical (41), effects (23), brief (17), contextual (6), novel (6), experimental (1), and role (1). One out of the 95 reasons given for attributing pragmatic ethics to the language of the questionnaire answers was somewhat questionable: "sees self as an agent of creating knowledge to share." It was given the status of somewhat questionable and not invalid outright. The rationales for this category seem to be highly consistent with the intent of the researcher.

Table 36

Validation of the Rationale for Assigning Pragmatic Ethics to Questionnaire Data

Rationale for Pragmatic Ethics Attribution	Idea	Valid?
Brevity implies pragmatism	Brief	Yes
Concerned with effects and less so with internal sensibilities	Effects	Yes
Concise answer (x4)	Brief (x4)	Yes
Concise answers (x2)	Brief (x2)	Yes
Defining a thing by looking at its effects (x2)	Effects (x2)	Yes
Depends on the details that is the effects	Effects	Yes
Ethical requirements will change with technology	Contextual	Yes
Ethics to fit the setting	Contextual	Yes
Explicit about assignment of rights to animals being in a cultural context	Contextual	Yes
Explicit pragmatic perspective	Practical	Yes
Focus on creating something new	Novel	Yes
Focused clearly on practice and not theories	Practical	Yes
Focused on observable systems results and not an inferred principle	Effects	Yes
Focused on the observables rather than the principles	Effects	Yes
Fuzzy and movable boundaries	Contextual	Yes
Gave a link instead of writing an answer + listened to practical advice	Practical	Yes
Harvesting-resources notion aligned with sustainability	Practical	Yes
Implicit in the position is the practice of the profession	Practical	Yes
In favor of scientific approach to ethical systems	Practical	Yes
Interested in the practice more than the theory (x2)	Practical (x2)	Yes
Investigating observable systems for intelligence based presumably on outcomes	Effects	Yes
Involved in developing new tools (x2)	Novel (x2)	Yes
Language implies a focus on practicality over theory	Practical	Yes
Look at effects and value outcomes more than conceptualization	Effects	Yes
Look at the effects of the thing of interest	Effects	Yes
Look at what the designers or implementers hope to accomplish	Effects	Yes
Looking at effects and limiting ethical scope to that	Effects	Yes
Looking at effects of objects of interest	Effects	Yes
Looking at the effects	Effects	Yes
Looking at the effects and results and uses	Effects	Yes
Looking at the effects of a thing	Effects	Yes
Looking at the effects of a thing instead of the thing itself	Effects	Yes
Looking at the practical application of a definition (x2)	Practical (x2)	Yes
Looking at the practical effects	Practical	Yes
Looking at what is and not at what one wants to see	Contextual	Yes

Rationale for Pragmatic Ethics Attribution	Idea	Valid?
Looking closely at the results of the research as their main feature	Effects	Yes
Looking for novel solutions	Novel	Yes
Looks at effects	Effects	Yes
Looks at the results of processes	Effects	Yes
Looks at the results of the object of study and not internal first principles	Effects	Yes
Made choice for practical reason	Practical	Yes
Mentions pragmatic as essential in science	Practical	Yes
No role for ethics except in utility or interest	Practical	Yes
Not focused on theory	Practical	Yes
Not looking for an ultimate truth but rather for a practical model	Practical	Yes
Novel solutions	Novel	Yes
Perspective is based on practicalities	Practical	Yes
Practical adaptation of language usage as needed	Practical	Yes
Practical analysis of the effects of unethical practices (x2)	Practical (x2)	Yes
Practical assessment of effects	Practical	Yes
Practical assessment of the issue leading to a working definition (x2)	Practical (x2)	Yes
Practical considerations	Practical	Yes
Practical focus on working hypothesis	Practical	Yes
Practical in that no other subject held interest	Practical	Yes
Practical insight into the process	Practical	Yes
Practical need or no need depends on the work at hand	Practical	Yes
Practical over theory	Practical	Yes
Reductionist looking at the effects of an object of interest	Effects	Yes
Refinement of the practice (x2)	Practical (x2)	Yes
Respondent has accepted the practicalities and constraints of their work	Practical	Yes
Sees self as an agent of creating knowledge to share	Role	?
Sees the value of testing the material world	Experimental	Yes
Short answer (x2)	Brief (x2)	Yes
Short answer + practical focus on performance	Practical	Yes
Short answer + recognized a need	Effects	Yes
Short answer that is rooted in the physical	Brief	Yes
Short answers (x3)	Brief (x3)	Yes
Short answers + external influences	Contextual	Yes
Short concise answer (x2)	Brief (x2)	Yes
Short concise answers	Brief	Yes
Short statement	Brief	Yes
The effect is that they are useful in some fields	Effects	Yes
The statement is short and practical	Practical	Yes

Rationale for Pragmatic Ethics Attribution	Idea	Valid?
Trusting the process of career opportunities to produce benefit	Practical	Yes
Unconcerned with implications	Practical	Yes
Uses the properties of an object of interest in practice	Practical	Yes
Wanting to have a clearer ethical system that is not burdened by theological notions	Practical	Yes
Willingness to adapt to practicalities	Practical	Yes
Wishing to innovate and ignore theoretical boundaries	Novel	Yes
Works in grant writing in a related field for practical reasons	Practical	Yes

The process of validation produced both an assessment of the consistency of the coding process and a revision of the results. They are based on induction, that is, the evidence supports their probable truth, based on that evidence and inference. The validity is therefore qualified by its context. The validation process required a reanalysis of the bases of the inferences made, and this process produced actionable results. The difficulty was limited to reassigning a small number of attributions from one ethical perspective (pragmatism) to one other ethical perspective (utilitarianism) and reflected a need for increased clarity. Validations for the other three sections of the questionnaire data analysis follow below.

Refining the ethical framework. The results of the validation process described above, plus notes taken while the initial analysis was undertaken, formed the basis of the findings in the "Refining the ethical framework" section. Weaknesses: The refinements that were made are qualified by the nature of the induction process.

Science, astrobiology, and machine life. Weaknesses: The observations given at the end of the "Science, astrobiology, and machine life" section were based on induction and are thus qualified by the nature of that process.

Suggested ethics. This section consisted of direct quotations of respondents' answers. Weaknesses: The choice of which answers to include or exclude was subjective, as was the induction process wherein answers of interest were assigned to one of several thematic categories that emerged during the process of reading them.

Recommendations for Policy Makers

A short document that provides recommendations for policy makers was devised from information gathered for or contained in this manuscript. It can be found in Appendix E. This section will describe some of the offerings contained therein.

The introduction leads with the question of autonomous vehicles and how humans might address the issue of decision-making when competing interests are at stake. Whether to save a driver or a bystander—when there is an imminent crash, and all else is equal—is a challenging dilemma (Bonnefon, Sharrif, & Rahwan, 2015). The author spent some time addressing this issue after writing the literature review chapter, and an answer is provided in the last section. Also in this introduction are four quotes from the questionnaire, each giving a different perspective on why more focus on ethics may be useful in different contexts. They come from both a planetary science and artificial intelligence perspective, and point towards the existence of a shared humanity.

Having introduced the topic of ethics with the introduction, the work next relates that people tend to consider ethics as restricted to caring for vulnerable populations, or to a philosophical stance like Kant's *categorical imperative* to act responsibly, or to applied ethics that they may be familiar with from a workplace setting. (These observations were taken from the results of the frequency analysis of the questionnaire data; see Table 26.) The text next introduces a rubric for looking at different ethical perspectives. The five

different ethical bases identified in the literature review are presented: personal, social, cultural, environmental, and quantitative. A metric for looking at seven complementary ethical perspectives (also derived from the literature review) is presented, along with advice on the importance of dialogue and generating respect for different perspectives. That finding arose during work with the content notes of the Skype conversations.

Finally, six recommendations are made. First, for the question of whether to place more value on a driver or on a bystander when there is an imminent crash, and all else is equal, I chose to promote the idea that the user of the vehicle ought to be free to set the value as they wish, with the proviso that either setting ought still be safer than having a human driver. The distribution of responsibility back to the individual promotes respect, as identified in the Skype conversation notes.

Second, a utilitarian argument for preserving microbial life found off-planet was presented—that at some point in the future a technologically advanced civilization will make contact with us. The biodiversity and genetic information we have here on Earth and that may conceivably be found on other planets may be of interest as a trade good and be a monetary resource at some point to build stability and peace between two technologically advanced worlds. This idea was developed while attending the 48th meeting of the Division for Planetary Sciences of the American Astronomical Society 16-21 October 2016, and speaking to attendees about comparative ethics. It can also be found in one of the cases in the literature review chapter.

A third recommendation was presented related to the rights of machines. Once machine life has reached a threshold for life (probably functional autonomy) it will need to be protected as other life is. This notion is interesting on a few levels: (a) The author

saw a presentation by Dr. Manuela Veloso at the De Lange Conference X on December 5, 2016 describing autonomous robots that perform environmental monitoring and other tasks in the multi-storey computer science complex of Carnegie Mellon University.

Functional autonomy already exists in these machines. (b) It is probably not any more controversial extending rights to machines than it was to extend rights to women 150 years ago. There is a long tradition of enlarging the scope of ethics as time goes on. This is both a pragmatic and a categorical approach.

The coming displacement of workers because of AI technology was also highlighted at the De Lange conference, and this forms the basis of the fourth recommendation, namely increased resources for training displaced workers.

A fifth recommendation was based on an answer from the questionnaire addressing whether humans ought to imbue robots with consciousness if it is possible to do so. A basis for an answer to this may be found in reframing the question to see that in this act humanity is creating a new life, and like any creation of life, the fundamental issue is one of consent by those doing the creating. In order to promote consent on such a broad issue, the recommendation was given to promote dialogue across different perspectives, an idea found both in the questionnaire responses and in the author's motivation for this research project. Promoting respect was the sixth recommendation; it was a general one. The recommendations are summarized briefly in Table 37, along with a short preliminary analysis of their comparative ethical worth.

Each of these topics could probably be expanded to be a salient documentary and reach many people. One hopes that some of these ideas do find a home in a wide range of settings and lead to more dialogue and more respect between people.

Table 37

Recommendations for Policy Makers, Plus an Assessment of Their Ethical Status

Recommendation	K	C	Ae	E	L	U	P
Users of autonomous vehicles ought to be given the choice to decide when to value a driver's life more than that of pedestrians.	yes	–	–	yes	–	yes	yes
Biodiversity, including that of microbes, ought to be preserved as a possible trade good for the future	yes	yes	yes	–	yes	yes	–
Protections for machines that exhibit functional autonomy should be put in place	yes	yes	yes	–	–	–	–
Workers displaced by AI technology ought to be offered retraining	yes	yes	yes	–	–	–	yes
A global dialogue should be undertaken to assess the consensus related to working to give machines consciousness	yes	yes	yes	–	yes	–	–
Respect for different ethical perspectives ought to be promoted	yes	yes	yes	–	yes	no	–

Note. K = Kantian, C = Care, Ae = Aesthetics, E = Evolutionary, L = Land, U = Utilitarian, P = Pragmatic. A dash signifies that it is not clear whether the perspective supports the recommendation, or that the perspective is neutral.

Lesson Plans

Two lesson plans were created out of the action of this project. They can be found in Appendix F. The first presents the concept of a strong inference in science—the idea that there should be several competing hypotheses in any study to help prevent confirmation bias (Platt, 1964). The topic was suggested by one of the questionnaire responses related to philosophy of work, Question 3:

My approach is a combination of thought experiment, a creative imaginative seeing of complex systems and relationships, and laboratory and field testing. Working with [a colleague] I engage in the combination of these systemic thought experiments and then the development of testable hypotheses which compete with alternative hypotheses in the field, as put forth by John Platt in his Science essay in 1964 "Strong Inference". I believe this a strong approach to science.

The lesson plan introduces the concepts of strong inference and confirmation bias. It is a student-centered lesson and is appropriate for middle school, high school, and college classes. The second lesson plan leads students through readings from some of the questionnaire answers to learn more about choosing a STEM career. Eleven of the responses to Question 1 about how their career was chosen are included. It is a student-centered lesson and is appropriate for middle school, high school, college, adult school, and career classes.

Summary

In the results from the Skype group discussion data and analysis, salient insights included: (a) the fields of machine life and astrobiology value creativity, and may be impacted both positively and negatively by the demands of academia; (b) machine life will need to be protected once it has reached a threshold where it can be called living, thus a definition for life will need to be developed that can mark this stage, and functional autonomy may be this marker; (c) how humans decide to treat animals is similar to how humans will decide to treat machine life and extraterrestrial life; (d) an appreciation for different ethical perspectives allows for well-informed choices when faced with questions of rights; (e) ethical perspectives have both personal and communicable components, and self-reflection can increase the amount of information that can be communicated; (f) professionalism is responsive to Kantian ethics due to the focus on role; (g) aesthetics and mood focus on perception and hence are potentially universal in their scope; and (h) Lie Algebras may be able to model different ethical frameworks, and lend some insight into their operation. Validation was addressed via a word count protocol which showed

varying degrees of subjectivity in the results—the most subjective being the mathematical focus of the third reflection activity.

In the results from the questionnaire data and analysis, salient insights included: (a) aesthetic and pragmatic attributions were the most common in general answers by far, and one may infer that a majority of these researchers take a pragmatic approach and are highly involved in culturally-mediated activity; (b) when asked specifically about ethics, respondents used language that referred to pragmatism, the ethics of care, or personal (Kantian) ethics most often. The ethics of care and personal (Kantian) ethics come to mind in the context of ethics specifically more than when the subject is not turned to ethics; (c) land-based ethics are not evident in the great majority of responses; and (d) evolutionary ethics and utilitarianism were opposed in some responses. Likewise, many of the given answers exhibited a large degree of passion, discipline, creativity, and humor. Validation or the quantitative analysis was addressed via a re-analysis of the rationales used in assigning ethical attributions to the responses, and initially found an improvement that needed to be made in six out of 390 data points, which was subsequently accomplished. Additional reflections on each of the results described in this chapter summary can be found in Appendix G.

The recommendations for policy makers included the following three novel findings based on concepts developed during the process of writing the manuscript: (a) users of autonomous vehicles ought to be given the choice to decide whether to value the driver's life more than that of pedestrians if the risk to each is equal; (b) biodiversity, including that of microbes, ought to be preserved as a possible trade good for the future; (c) a global dialogue should be undertaken to assess the consensus related to working to

give machines consciousness. The finding that workers displaced by AI technology ought to be offered retraining is already widespread and was emphasized based on questionnaire data. The recommendations also reiterated the following two findings: (a) protections for machines that exhibit functional autonomy should be put in place; and (b) respect for different ethical perspectives ought to be promoted.

The two lesson plans were developed around an idea mentioned in one of the questionnaire answers (strong inference) that informs scientific methodology; and on the rich offering of stories that questionnaire respondents provided related to career path choices. Lessons are dynamic and student-centered. They can be adapted to various settings in secondary, tertiary, and adult education.

CHAPTER V: DISCUSSION AND CONCLUSIONS

This project arose out of several years of discussion and work related to how life is defined, what constitutes life and living, and whether large-scale phenomena, such as the universe itself, could be considered living. Many of these discussions with professionals working in the fields of astrobiology, origin of life, artificial life, sustainability (and others) repeatedly brought up practical concerns not about the science itself, but instead about how it would be applied in society. From this the idea that an important question to answer that would help these various researchers came in the form of a challenge to find a useful framework from which to address different perspectives about our obligations to our work and to those who would be impacted by our work.

The result of gathering a large body of literature on the topic and exploring in general the history of cultural developments is that ethical perspectives based on personal, social, cultural, ecological, or quantitative themes may be orthogonal to each other. This finding is in addition to the idea that there are two prevailing ethical frameworks: deontology and consequentialism. To see what this means, first let us look more deeply at what deontology and consequentialism describe and how they are different.

Complementary Ethical Perspectives

Deontology focuses on ethical obligations, and that these obligations arise out of features inherent in thinking clearly about a role. Obligations are not only a result of foreseeing the consequences of actions, but rather of thinking clearly about one's role. Motivation is personal.

Consequentialism focuses on ethical obligations, and that these obligations arise out of calculating potential causes and effects. Obligations are not only a result of thinking clearly about the role a person takes on, but rather of foreseeing consequences of actions. Motivation is objective.

Such differences of perspective, as described above for deontology and consequentialism, can be succinctly stated as *internal* and *external* frameworks, respectively, focusing on the *thing itself* (deontology) or its *effects* (consequentialism). Thus, personal, social, cultural, and ecological perspectives appear to be distinct ways of thinking about relationships. The motivations of caring for oneself or a person, group, or ecology are complements to each other, and these can be seen as different types of deontological perspectives. These complementary perspectives can be treated separately in order to respect their inherent relational differences.

Likewise, so-called objective measures of causes or effects always contain assumptions and errors in how relevant questions are framed and calculations are carried out. In this text the term *quantitative* has been used instead of *objective* with the idea that different quantitative perspectives might be based on different assumptions. The process of calculating distinct values for goods or services (utilitarianism) has been contrasted with re-evaluating data to arrive at new inventions or ways of doing things (pragmatism) as only two of perhaps many different quantitative perspectives. These are complementary to each other and place a different value on progress. They can be seen as two types of consequentialist perspectives.

The identification of different ethical perspectives suggests a few directions for future research. First, it seems a striking conclusion that aesthetics as an ethical

perspective may have a universal appeal. Within aesthetics there need not be an appeal to theory, but rather to experience and perception that determine how objects are aesthetically judged. Thus, the type of learning related to aesthetic judgements is not academic per se yet has the potential to reach people broadly.

Second, since there are many things in human and animal behavior that are learned by example (Tomasello et al., 1993), it would be interesting to study and determine the extent to which ethics are learned by example. With this research direction there is also the complementary idea that ethical perspectives may be context-specific. For example, the dearth of land ethics attributions found in a study dataset might be related to respondents' presumed lack of time in natural settings. In concert, the effects of context (or experience) and suitable examples from which to learn may be seen as a scientific unknown.

Third, notwithstanding the above, ethical perspectives are not a scientific area of knowledge, but rather a personal one. Ethical perspectives are a composite of personal and communicable information. The idea that there might be an underlying structure for how people think about ethics that may be made explicit mathematically rests on the ability of mathematics to describe relationships and valuations in a way that takes into account the dilemmas sometimes faced in making decisions, and also what we call the personal or internal aspects of ourselves. This is a tall order for a mathematical structure, yet Lie algebras, with their treatment of symmetry groups where elements are continuous rather than discrete, might be suitable. Models can help to explore the implications of a set of ethical perspectives more clearly, and perhaps could do more than this preliminary work has done in being able to say whether the elements of any set of distinct ethical

perspectives are orthogonal (independent) or overlap, and also whether the set itself is complete. This project so far has produced only tentative observations. The initial impression is that humanity is rich with different perspectives, and this attempt at categorizing them has contributed a tentative framework to help bring people together in appreciation for those differences. It is a more complex treatment than the current practice of applied ethics, for example, which typically casts itself as a commentary on behaviors within a profession (e.g., medical ethics). A comparative framework such as that described in the Chapter III case studies could make the treatment richer.

Personality Differences and Competition

Psychometric analysis can be applied in a way that divides people into groups, and this analysis may create further social division. For example, in 2016, both the exit vote in the UK and the presidential elections in the USA saw the winning side of each employing the firm Cambridge Analytica to target advertising and outreach based on the personality profiles of users, which itself had been gathered from social media data (Ramswell, 2017). Whether the data proved decisive in identifying voters who were likely to be swayed to one side is not clear, but the social media platforms became increasingly divisive at this time, and targeted advertising served to highlight differences between groups. If the use of these data produced outcomes that have led to greater animosity between groups it could mean that this kind of divisiveness will continue to worsen as social-media-based data analytics and communications for elections continue to increase in popularity.

The key idea behind the psychometric application used by Cambridge Analytica and other similar firms is to find patterns of behavior in social media and match them

with personality and demographic profiles. It is a process similar to matching questionnaire responses (or observations about a group discussion participant) to different ethical perspectives. The aim of the former is to win elections. The aim of the latter is to learn more about the human condition. They are different applications of similar explorations.

Part of the motivation of this project is as a response to the growing automation of what had been human-based judgement roles in administrative and managerial fields. Computers are now used for tasks that used to have human input. One might worry that the computer-based choices will not include enough input from under-represented populations or perspectives that may not have monetization as their goal. These computer-based choices may fail to provide for future growth in our humanity. In response, this project and others like it may include a set of complementary ethical perspectives in a consistent way, so that such important things as the land-based ethics or an ethic of care will be represented fully within these machine systems—despite the general trend towards automation. If the research work is very well received it may lead to further research and application, and this may preemptively prevent some more reductionist views.

Note that the process of developing a framework of complementary ethical systems (as found in Chapter III) was discursive. The process of structured reflections that are iterative can bring many distinct lines of reasoning forward, in the same way that discussions led for the sake of gaining insight tend to bring forward several distinct lines of reasoning; reflective analysis is akin to discussion (Freshwater, 2007). A dataset that includes complementary lines of reasoning will be richer than a monotyped one.

In general, scientific research and communication are creative endeavors. Scientists work to generate and share new information—a process that is akin to the creation of artwork, for example, as data generation, analysis, and discussion can be seen as similar to canvas preparation, sketching, underpainting, laying out mid-tone colors, laying out dark tones, laying out light tones, and highlights—not that each stage in each process is equivalent, but rather that the processes themselves make use of distinct steps that are successive and may be modified to promote final products that will be taken up by the public. The study of human decision-making within the computer science community may tend towards creative embodiments of different perspectives by virtue of the creativity inherent in research.

Parental Responsibilities Towards Machine Life

Technological developments, such as the development of autonomous machines or of space craft able to discover extraterrestrial life forms, come with a responsibility that is parallel to the care that creating offspring engenders—and a more global discussion is warranted. Note that discovery and creation are distinct actions. Perceived duties towards living organisms that one discovers are therefore likely to be different from perceived duties towards machine life.

When parents decide to have children, they often do so with a great deal of care, foresight, and planning, as if it is the most important thing that they will do in their lives. Planning can include things both in the short-term, such as buying furniture, painting a room, buying supplies, etc., and in the long-term, such as putting away money for university schooling, and others. Emotional work may be done as well, and may include imagining how one's role will evolve as a parent, imagining how a child will respond in

various conditions, and many, many other emotionally deep activities that are meant to prepare a safe place for the new child. The idea behind planning is to prepare a path for the child to help it be successful in life. Many parents feel strongly about this.

Yet, humanity is currently involved in the creation of new offspring in the form of autonomous machines, and very little planning has been done to prepare a path for machine life to help it be successful on its own terms. Science fiction has been addressing this issue in a speculative fashion for decades, for example, with Isaac Asimov's three laws for robots, but the treatment envisions machine life as forever subservient.

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law. (Asimov, 1950)

As with the creation of babies, perhaps humanity will wish to take on parent-like roles with its machine creations at some point. This notion is based upon the idea that offspring (living machines) and creator (humans) are involved in a developing relationship with each other. Just as one would wish for children to surpass their parents, so too one may wish for living machines to surpass the civilization that created them. There is the possibility for this to happen well if autonomous machines are treated with dignity and afforded the same rights as people.

Information Technology is Distinct

Computer systems are just one part of a larger field of information technology, yet the idea of robots—made possible via advancements in computing—can be seen as a special category that society has embraced in its fictional accounts of the future. Machine

life is treated with a romantic notion of quasi-anthropomorphism, presenting the perspectives of the not-quite-human machines in such movies as *Blade Runner* (Deeley & Scott, 1982), *Star Wars* (Kurtz & Lucas, 1977), *Tron* (Kushner & Lisberger, 1982), and many others. The stories and speculations are remarkably abundant. Moreover, they describe situations that are, in fact, precedent to the development of the technologies described. Novel ethical prescriptions, as well, predate these technologies.

In general, ethical dilemmas may occur before, during, or after some technology has been developed and employed. Clearly many of the discussions centered on ethical concerns do not predate the technological developments that engendered those concerns, but instead may follow by years or centuries—for example, the development of navigation technology and merchant ships which allowed for an immense slave trade starting in the fifteenth century lasted four hundred years before the cultures involved in the exploitation developed an ethical perspective that would dismantle it. The technology led the development of the ethics.

Today there is a similar issue with the exploitation of natural resources. The development of the internal combustion engine and the use of fossil fuels dating from the industrial revolution of the eighteenth and nineteenth centuries has been met only recently with deeper reflection in the societies that employ these technologies, to the extent that ethical obligations towards an ecosystem are only now being proposed (Anderberg, 1998). It is only in hindsight that applicable ethical perspectives are being developed, and these are too late to prevent much of the devastation (Spash, 1993).

Notwithstanding, innovation in information technology is associated with a flowering of imaginative ethical considerations that predate some of the technologies that

they address. Historically, the most significant innovation in information technology is the development of writing. This technology developed independently in different places (Lawler, 2001; Li et al., 2003; Marcus, 1976), and in many there appears alongside the written word a reverence for text that is seen in the development of religious perspectives based on text.

The development of writing is associated with new changes to how edicts or law are conceived of and communicated, for example, as a legal code (Thomas, 1995), and also with the development of perhaps arbitrary or odd ethical codes and laws (Hasnas, 1995). Religious texts are abundant with ethical considerations that today seem not to be applicable, for example the Pythagoreans not eating beans (Scarborough, 1982), or Israelites not wearing garments made from two different kinds of material (Hoffnung et al., 1989). The development of information technology (in this case, writing) is associated with novel, speculative attempts at ethical prescriptives.

The invention of computers matches the inventions of writing and of print as an information technology with an immense transformative power for civilization (Ferris, 2002). Devices containing computers are ubiquitous, and applications for computing touch most areas of most peoples' lives on Earth, and all of the terrestrial environments are impacted to some extent by systems that employ computers. One might infer from the earlier abundance of religious and moralistic texts as writing developed that advances in computing and machine life may be met with a large, novel set of prescriptions for how people ought to act—this time coming from the context of computer-based applications, brain-machine interfaces, and machine life.

If there is to be a new set of developments associated with the new information technology, these imaginative ethics may become superfluous with time, just as many religious texts developed when the invention of writing was in the not-too-distant past are not now followed closely. These developments would be in contrast innovations in technology that impact the physical environment more directly and often predate the development of relevant ethics. Their relevant ethics address challenges only in hindsight. Thus, machine life and extraterrestrial life are likely to have different ethical trajectories. Life discovered on Mars, for example, may not lead to a new ethical perspective for hundreds of years, whereas a new ethical perspective that includes how living machines may be integrated into society may produce an immense body of speculative ethics that will be a part of the human state of affairs for millenia.

Conclusion

In the context of their work, neither group of researchers (astrobiologists and computer scientists) is looking for a specific definition of life. Instead they are seeking ethical frameworks to describe how to deal with any new developments that may be seen as life-like. This difference allows for both groups to pursue new possibilities and still have frameworks of ethical behavior. Distinct ethical perspectives can be seen as complements to each other that help discussion and innovation rather than hinder it.

REFERENCES

- Anderberg, S. (1998). Industrial metabolism and the linkages between economics, ethics and the environment. *Ecological Economics*, 24(2), 311-320. 10.1016/S0921-8009(97)00151-1
- Anderson, J. G., Toohey, D. W., & Brune, W. H. (1991). Free radicals within the Antarctic vortex: The role of CFCs in Antarctic ozone loss. *Science*, 251(4989), 39-46. doi: 10.1126/science.251.4989.39
- Ash, J., Novak, C., & Scheideler, S. E. (2003). The fate of genetically modified protein from Roundup Ready soybeans in laying hens. *The Journal of Applied Poultry Research*, 12(2), 242-245. doi: 10.1093/japr/12.2.242
- Asimov, I. (1950). *I, robot*. New York: Gnome Press. 253 pp.
- Back, T., Fogel, D. B., & Michalewicz, Z. (Eds.). (1997). *Handbook of evolutionary computation*. Bristol, UK: IOP Publishing. 988 pp.
- Banerjee, S. (2012). *Arctic voices: Resistance at the tipping point*. New York: Seven Stories Press. 576 pp.
- Bayly, C. A. (1996). *Empire and information: Intelligence gathering and social communication in India, 1780–1870*. Cambridge University Press. 428 pp.
- Bentham, J. (1780/1823/1879). *An Introduction to the Principles of Morals and Legislation*. Oxford: Clarendon. 416 pp.
- Beyer, P., Al-Babili, S., Ye, X., Lucca, P., Schaub, P., Welsch, R., & Potrykus, I. (2002). Golden rice: Introducing the β -carotene biosynthesis pathway into rice endosperm by genetic engineering to defeat vitamin A deficiency. *The Journal of nutrition*, 132(3), 506S-510S. PMID: 11880581

- Bingham-Hall, P. (2016). *Garden city mega city: Rethinking cities in the age of global warming*. Oxford: Pesaro Publishing. 384 pp.
- Bonnefon, J. F., Shariff, A., & Rahwan, I. (2015). Autonomous vehicles need experimental ethics: Are we ready for utilitarian cars?. *arXiv preprint arXiv:1510.03346*. Retrieved from <https://pdfs.semanticscholar.org/13d4/56d4c53d7b03b90ba59845a8f61b23b9f6e8.pdf>
- Bonnefon, J. F., Shariff, A., & Rahwan, I. (2016). The social dilemma of autonomous vehicles. *Science*, 352(6293), 1573-1576. doi: 10.1126/science.aaf2654
- Borovik, A. (2009). *Mathematics under the microscope: Notes on the cognitive aspects of mathematical practice*. Providence: American Mathematical Society. 331 pp.
- Bose, S. (2012). Historic buildings at Chitpur in Kolkata: Problems and prospects through urban conservation and planning. *The Planning Review*, 48(1), 68-82. doi: 10.1080/02513625.2012.702987
- Bronowski, J. (1956). Science and human values. *Higher Education Quarterly*, 11(1), 26-42. doi: 10.1111/j.1468-2273.1956.tb00909.x
- Bruner, J. (1985). Models of the learner. *Educational Researcher*, 14(6), 5-8. Retrieved from <http://www.jstor.org/stable/1174162>
- Burney, D. A., & Flannery, T. F. (2005). Fifty millennia of catastrophic extinctions after human contact. *Trends in Ecology & Evolution*, 20(7), 395-401. doi: 10.1016/j.tree.2005.04.022
- Campbell, R. (Ed.) (2014). *Violence and civilization: Studies of social violence in history and prehistory*. Oxford: Oxbow Books. 160 pp.

- Carmichael, P. A. (1949). The logical ground of deontology. *The Journal of Philosophy*, 46(2), 29-41. doi: 10.2307/2020187
- Cavicchioli, R. (2004, July). Extremophiles and the search for extraterrestrial life. *Astrobiology*, 2(3), 281-292. doi: 10.1089/153110702762027862
- Connell, J., & Viola, P. (1990, May). Cooperative control of a semi-autonomous mobile robot. In *Robotics and Automation, 1990. Proceedings., 1990 IEEE International Conference on* (pp. 1118-1121). IEEE. doi: 10.1109/ROBOT.1990.126145
- Conrad, L. (2014). Integration and the liberal arts: A historical overview, *On the Horizon*, 22(1), 46-56. doi: 10.1108/OTH-11-2013-0045
- Crockenberg, S., & Litman, C. (1990). Autonomy as competence in 2-year-olds: Maternal correlates of child defiance, compliance, and self-assertion. *Developmental Psychology*, 26(6), 961. doi: 10.1037/0012-1649.26.6.961
- Da, B., Gupta, A., Ong, Y. S., & Feng, L. (2016, February). The boon of gene-culture interaction for effective evolutionary multitasking. In *Australasian Conference on Artificial Life and Computational Intelligence* (pp. 54-65). Springer International Publishing. doi: 10.1007/978-3-319-28270-1_5
- Davis, P. J., & Hersh, R. (1981). *The mathematical experience*. Boston: Birkhäuser. 464 pp.
- Dawe, D., & Unnevehr, L. (2008). Crop case study: GMO golden rice in Asia with enhanced vitamin A benefits for consumers. *AgBioForum*, 10(3), 4. Retrieved from <http://www.agbioforum.org/v10n3/v10n3a04-unnevehr.bak>

- de Vos, W. M. (1999). Safe and sustainable systems for food-grade fermentations by genetically modified lactic acid bacteria. *International Dairy Journal*, 9(1), 3-10. doi: 10.1016/S0958-6946(99)00038-2
- Deeley, M. (Producer), & Scott, R. (Director). (1982). *Blade runner* [Motion Picture]. USA: Warner Bros.
- Des Marais, D. J., Nuth, J. A., III, Allamandola, L. J., Boss, A. P., Farmer, J. D., Hoehler, T. M., ... Spormann, A. M. (2008, October). The NASA astrobiology roadmap. *Astrobiology*, 8(4), 715-730. doi: 10.1089/ast.2008.0819
- Dijk, A., Slaper, H., den Outer, P. N., Morgenstern, O., Braesicke, P., Pyle, J. A., ... & Tourpali, K. (2013). Skin cancer risks avoided by the Montreal Protocol—Worldwide modeling integrating coupled climate–chemistry models with a risk model for UV. *Photochemistry and Photobiology*, 89(1), 234-246. doi: 10.1111/j.1751-1097.2012.01223.x
- Donaldson, S., & Kymlicka, W. (2011). *Zoopolis: A political theory of animal rights*. Oxford University Press. 352 pp.
- El-Fadel, M., Zeinati, M., Ghaddar, N., & Mezher, T. (2001). Uncertainty in estimating and mitigating industrial related GHG emissions. *Energy Policy*, 29(12), 1031-1043. doi: 10.1016/S0301-4215(01)00033-7
- Elliot, P. A. (2010). *Enlightenment, modernity and science: Geographies of scientific culture and improvement in Georgian England*. London: Tauris. 352 pp.
- Ethnologue. (2016). Ethnologue | Languages of the world. Retrieved from <https://www.ethnologue.com>

- Farman, J. C., Gardiner, B. G., and Shanklin, J. D. (1985). Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction. *Nature*, 315, 207-210. Retrieved from <http://eesc.columbia.edu/courses/v1003/readings/Farman.etal.1985.pdf>
- Feinberg, J. (2016). Wordle – beautiful word clouds. Retrieved from <http://www.wordle.net/>
- Ferris, S. P. (2002). Writing electronically: The effects of computers on traditional writing. *Journal of Electronic Publishing*, 8(1), 104. doi: 10.3998/3336451.0008.104
- Fox, M. E., Lemmon, M. J., Mauchline, M. L., Davis, T. O., Giaccia, A. J., Minton, N. P., & Brown, J. M. (1996). Anaerobic bacteria as a delivery system for cancer gene therapy: in vitro activation of 5-fluorocytosine by genetically engineered clostridia. *Gene therapy*, 3(2), 173-178. PMID: 8867865
- Frankl, V. E. (1946). *Man's search for meaning: An introduction to logotherapy*. London: Hodder & Stoughton. 137 pp.
- Freeland, S. J., & Hurst, L. D. (2004). Evolution encoded. *Scientific American-American Edition*, 290(4), 84-91. Retrieved from http://wps.prenhall.com/wps/media/objects/12330/12626747/myanthropologylibrary/PDF/BA_SCIAM_15_Freed_Hurst_562.pdf
- Freshwater, D. (2007). Dialogue, conversation and discussion: Reflection upon languaging relationship. *Journal of Psychiatric and Mental Health Nursing*, 14(5), 431-432. doi: 10.1111/j.1365-2850.2007.01140.x

- Fynn-Paul, J. (2009). Empire, monotheism and slavery in the greater Mediterranean region from antiquity to the early modern era. *Past & Present*, 205(1), 3-40.
Retrieved from <http://www.jstor.org/stable/40586930>
- Gabay, A. J. (2004). *The covert enlightenment: Eighteenth-century counterculture & its aftermath*. West Chester, Pennsylvania: Swedenborg Foundation Publishers. 304 pp.
- Gabriel, R. (2002). *The Great Armies of Antiquity*. Westport, Connecticut: Praeger. 456 pp.
- Goldberg, D. E., & Holland, J. H. (1988). Genetic algorithms and machine learning. *Machine Learning*, 3(2), 95-99. doi: 10.1023/A:1022602019183
- Guba, E. G., & Lincoln, Y. S. (1982). Epistemological and methodological bases of naturalistic inquiry. *Educational Communication and Technology Journal*, 30(4), 233-252. doi: 10.1007/BF02765185
- Gupta, R., & Singh, R. L. (2017). Genetically modified organisms (GMOs) and environment. In *Principles and Applications of Environmental Biotechnology for a Sustainable Future* (pp. 425-465). Springer Singapore. doi: 10.1007/978-981-10-1866-4_14
- Halley, E. (1687). Ode (O. Steinmayer, Trans.). In I. Newton, *Philosophiae Naturalis Principia Mathematica*. Retrieved from http://www-history.mcs.st-and.ac.uk/PrintHT/Newton_poetry.html
- Hanh, Thich Nhat. (1987). *Old path white clouds: Walking in the Footsteps of the Buddha*. Berkeley, California, USA: Parallax Press. 600 pp.

- Harley, D., Acord, S. K., Earl-Novell, S., Lawrence, S., & King, C. J. (2010). *Assessing the future landscape of scholarly communication: An exploration of faculty values and needs in seven disciplines*. UC Berkeley: Center for Studies in Higher Education. Retrieved from: <https://escholarship.org/uc/item/15x7385g>
- Haslberger, A. (2001). GMO contamination of seeds. *Nature Biotechnology*, 19(7), 613-613. doi: 10.1038/90201
- Hasnas, J. (1995). The myth of the rule of law. *Wisconsin Law Review*, 1995, 199-233. Retrieved from <http://faculty.msb.edu/hasnasj/gtwebsite/MythFinalDraft.pdf>
- Heidegger, M. (1959/1971). *On the way to language*. New York: Harper & Row. 208 pp.
- Hersh, R., (1999). *What is mathematics, really?* Oxford. 368 pp.
- Hilbeck, A., Binimelis, R., Defarge, N., Steinbrecher, R., Székács, A., Wickson, F., ... & Novotny, E. (2015). No scientific consensus on GMO safety. *Environmental Sciences Europe*, 27(1), 1. doi: 10.1186/s12302-014-0034-1
- Hinkle, A., & Batzle, M. (2006). Heavy oils: A worldwide overview. *The Leading Edge*, 25(6), 742-749. doi: 10.1190/1.2210073
- Hoeve, M., Dubas, J. S., Eichelsheim, V. I., Van der Laan, P. H., Smeenk, W., & Gerris, J. R. (2009). The relationship between parenting and delinquency: A meta-analysis. *Journal of Abnormal Child Psychology*, 37(6), 749-775. doi: 10.1007/s10802-009-9310-8
- Hoffnung, R., Aizenberg, D., Hermesh, H., & Munitz, H. (1989). Religious compulsions and the spectrum concept of psychopathology. *Psychopathology*, 22(2-3), 141-144. doi: 10.1159/000284587
- Höhne, N., Wartmann, S., Herold, A., & Freibauer, A. (2007). The rules for land use, land

- use change and forestry under the Kyoto Protocol—lessons learned for the future climate negotiations. *Environmental Science & Policy*, 10(4), 353-369. doi: 10.1016/j.envsci.2007.02.001
- HRAF. (2016). Outline of world cultures list | Human relations area files. Retrieved from <http://hraf.yale.edu/resources/reference/outline-of-world-cultures-list/>
- Hudson, M., & Wunsch, C. (Eds.) (2004). *Creating economic order: Record-keeping, standardization, and the development of accounting in the ancient Near East*. Bethesda, Maryland: CDL Press. 354 pp.
- IBM. (2017). Personality insights | IBM Watson developer cloud. Retrieved from <https://www.ibm.com/watson/developercloud/personality-insights.html>
- Ilardo, M., Meringer, M., Freeland, S., Rasulev, B., & Cleaves II, H. J. (2015). Extraordinarily adaptive properties of the genetically encoded amino acids. *Scientific Reports*, 5, 9414. doi: 10.1038/srep09414
- Innis, H. A. (2007). *Empire and communications*. Lanham, Maryland: Rowman & Littlefield. 288 pp.
- IPCC. (2013/2014). *Fifth assessment report (AR5)*. Intergovernmental Panel on Climate Change. Retrieved from <https://www.ipcc.ch/report/ar5/>
- Johnson, J. G., Cohen, P., Gould, M. S., Kasen, S., Brown, J., & Brook, J. S. (2002). Childhood adversities, interpersonal difficulties, and risk for suicide attempts during late adolescence and early adulthood. *Archives of General Psychiatry*, 59(8), 741-749. doi: 10.1001/archpsyc.59.8.741
- Kak, S. (2000). Active agents, intelligence and quantum computing. *Information Sciences*, 128(1), 1-17. doi: 10.1016/S0020-0255(00)00043-8

- Kane, P. (2005). *The play ethic: A manifesto for a different way of living*. London: Pan Macmillan. 320 pp.
- Kant, I. (1755). *Universal natural history and theory of heaven*. Königsberg: Johann Friedrich Petersen. 162 pp.
- Kant, I. (1781). *Critique of pure reason*. Königsberg: Johann Friedrich Hartknoch. 785 pp.
- Kant, I. (1784). Answering the question: What is enlightenment? *Berlinische Monatsschrift*. Retrieved from <http://www.columbia.edu/acis/ets/CCREAD/etscc/kant.html>
- Kant, I. (1785). *Groundwork of the metaphysic of morals*. Riga: Johann Friedrich Hartknoch. 160 pp.
- Kinley, D., & Tadaki, J. (2004). From talk to walk: The emergence of human rights responsibilities for corporations at international law. *Virginia Journal of International Law*, 44(4), 931-1023. Retrieved from: <http://ssrn.com/abstract=923360>
- Klümper, W., & Qaim, M. (2014). A meta-analysis of the impacts of genetically modified crops. *PloS one*, 9(11), e111629. doi: 10.1371/journal.pone.0111629
- Kosoy, N., & Corbera, E. (2010). Payments for ecosystem services as commodity fetishism. *Ecological Economics*, 69(6), 1228-1236. doi: 10.1016/j.ecolecon.2009.11.002
- Kurtz, G. (Producer), & Lucas, G. (Director). (1977). *Star wars* [Motion Picture]. USA: 20th Century Fox.
- Kushner, D. (Producer), & Lisberger, S. (Director). (1982). *Tron* [Motion Picture]. USA:

Walt Disney.

Laikre, L., Schwartz, M. K., Waples, R. S., Ryman, N., & GeM Working Group. (2010).

Compromising genetic diversity in the wild: unmonitored large-scale release of plants and animals. *Trends in Ecology & Evolution*, 25(9), 520-529. doi:

10.1016/j.tree.2010.06.013

Lamb, C. (1797/1909). A vision of repentance. In W. S. Braithwaite (Ed.), *The Book of Georgian Verse*. New York: Brentano's. 1313 pp.

Lawler, A. (2001). Writing gets a rewrite. *Science*, 292(5526), 2418-2420. doi:

10.1126/science.292.5526.2418

Le, K., Bilgir, O., Bianchini, R., Martonosi, M., & Nguyen, T. D. (2010). Managing the cost, energy consumption, and carbon footprint of internet services. *ACM SIGMETRICS Performance Evaluation Review*, 38(1), 357-358. doi:

10.1145/1811039.1811085

10.1145/1811039.1811085

Leff, L. G., & Leff, A. A. (1996). Use of green fluorescent protein to monitor survival of genetically engineered bacteria in aquatic environments. *Applied and Environmental Microbiology*, 62(9), 3486-3488. PMID: 8795242

Environmental Microbiology, 62(9), 3486-3488. PMID: 8795242

Li, X., Harbottle, G., Zhang, J., & Wang, C. (2003). The earliest writing? Sign use in the seventh millennium BC at Jiahu, Henan Province, China. *Antiquity*, 77(295), 31-44. doi: 10.1017/S0003598X00061329

44. doi: 10.1017/S0003598X00061329

Lipton, E. (2015, September 5). Food industry enlisted academics in GMO lobbying war, emails show. *New York Times*. Retrieved from

[http://www.lauhala.com/hinano/20150908-011706-Food-Industry-Enlisted-](http://www.lauhala.com/hinano/20150908-011706-Food-Industry-Enlisted-Academics-in-GMO-Lobbying-War-(NY-Times-9-5-2015).pdf)

[Academics-in-GMO-Lobbying-War-\(NY-Times-9-5-2015\).pdf](http://www.lauhala.com/hinano/20150908-011706-Food-Industry-Enlisted-Academics-in-GMO-Lobbying-War-(NY-Times-9-5-2015).pdf)

Mäder, J. A., Staehelin, J., Peter, T., Brunner, D., Rieder, H. E., & Stahel, W. A. (2010).

Evidence for the effectiveness of the Montreal Protocol to protect the ozone layer.

Atmospheric Chemistry and Physics, 10(24), 12161-12171. doi: 10.5194/acp-10-

12161-2010

Marcus, J. (1976). The origins of Mesoamerican writing. *Annual Review of*

Anthropology, 5(1), 35-67. doi: 10.1146/annurev.an.05.100176.000343

Marland, G., Boden, T. A., Andres, R. J., Brenkert, A. L., & Johnston, C. A. (2007).

Global, regional, and national fossil fuel CO₂ emissions. In *Trends: A*

Compendium of Data on Global Change, Oak Ridge, Tennessee: Carbon Dioxide

Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of

Energy. Retrieved from <http://cdiac.ornl.gov/trends/emis/overview>

McLuhan, M. (1974). Francis Bacon: Ancient or modern?. *Renaissance and Reformation*

/ Renaissance et Réforme, 10(2), 93-98. Retrieved from

<http://www.jstor.org/stable/43464885>

Metz, B., Solomon, S., Kuipers, L., Andersen, S. O., Davidson, O., Pons, J., ... & Meyer,

L. (2005). *Safeguarding the ozone layer and the global climate system: Issues related*

to hydrofluorocarbons and perfluorocarbons. Cambridge, England. UNT Digital

Library. Retrieved from <http://digital.library.unt.edu/ark:/67531/metadc12053/>

Mill, J. S. (1859). *On liberty*. London: Parker, Son & Strand. 112 pp.

Mill, J. S. (1861/1863). *Utilitarianism*. London: Parker, Son & Bourn. 88 pp.

Minnameier, G. (2005). Developmental progress in ancient Greek ethics. *European*

Journal of Developmental Psychology, 2(1), 71-99. doi:

10.1080/17405620444000274a

Mullen, L. (2013: July 23). Forming a definition for life: Interview with Gerald Joyce.

Astrobiology Magazine. Retrieved 2 March 2016 from

<http://www.astrobio.net/interview/forming-a-definition-for-life-interview-with-gerald-joyce/>

Newman, P. A. (2010). Chemistry and dynamics of the Antarctic ozone hole. In *The Stratosphere: Dynamics, Transport, and Chemistry* (L. M. Polvani, A. H. Sobel and D. W. Waugh, Eds.). Washington, D.C.: American Geophysical Union. doi: 10.1002/9781118666630.ch9

Newton, I. (1687/1726/1846). *Philosophiae naturalis principia mathematica* (3rd ed.) [Newton's Principia. The Mathematical Principles of Natural Philosophy] (A. Motte, Trans.). New York: Daniel Adee. 586 pp.

Nickles, T. (1994). Enlightenment versus romantic models of creativity in science—and beyond. *Creativity Research Journal*, 7(3-4), 277-314. doi: 10.1080/10400419409534535

Nicolia, A., Manzo, A., Veronesi, F., & Rosellini, D. (2014). An overview of the last 10 years of genetically engineered crop safety research. *Critical Reviews in Biotechnology*, 34(1), 77-88. doi: 10.3109/07388551.2013.823595

Padgett, S. R., Kolacz, K. H., Delannay, X., Re, D. B., LaVallee, B. J., Tinius, C. N., ... & Peschke, V. M. (1995). Development, identification, and characterization of a glyphosate-tolerant soybean line. *Crop Science*, 35(5), 1451-1461. doi: 10.2135/cropsci1995.0011183X003500050032x

- Painter-Morland, M. (2015). Philosophical assumptions undermining responsible management education. *Journal of Management Development*, 34(1), 61-75. doi: 10.1108/JMD-06-2014-0060
- Pearman, G. I., & Jäger, J. (1989). Greenhouse: planning for climate change. *Environment: Science and Policy for Sustainable Development*, 31(5), 25-27. doi: 10.1080/00139157.1989.9928943
- Peirce, C. S. (1878). How to make our ideas clear. *Popular Science Monthly*, 12, 286-302. Retrieved from <http://www.gornahoor.net/library/HowToMakeOurIdeasClear.pdf>
- Pinker, S. (2011). *The better angels of our nature: Why violence has declined*. New York: Viking. 832 pp.
- Pitts, J. (2003). Legislator of the world? A rereading of Bentham on colonies. *Political Theory*, 31(2), 200-234. doi: 10.1177/0090591702251009
- Platt, J. R. (1964). Strong inference. *Science*, 146(3642), 347-353. doi: 10.1126/science.146.3642.347
- Pleasants, J. M., & Oberhauser, K. S. (2013). Milkweed loss in agricultural fields because of herbicide use: effect on the monarch butterfly population. *Insect Conservation and Diversity*, 6(2), 135-144. doi: 10.1111/j.1752-4598.2012.00196.x
- Premet, A., & Strade, H. (2006). Classification of finite dimensional simple Lie algebras in prime characteristics. *Contemporary Mathematics*, 413, 185. Retrieved from <https://arxiv.org/abs/math/0601380>

- Qaim, M. (2009). The economics of genetically modified crops. *Annual Review of Resource Economics*, 1(1), 665-694. doi:
10.1146/annurev.resource.050708.144203
- Qian Ying Qian, Ma Ke Ping, Sang Wei Guo, and Wei Wei. (1999). Terminator technology and biosafety. *Chinese Biodiversity*, 1999-02. Retrieved from
http://en.cnki.com.cn/Article_en/CJFDTOTAL-SWDY902.011.htm
- Ramswell, P. Q. (2017). Derision, division—decision: parallels between Brexit and the 2016 US presidential election. *European Political Science*, 1-16. doi:
10.1057/s41304-017-0112-0
- random.org (2016). RANDOM.ORG – True random number service. Retrieved from
<https://www.random.org/integers/>
- Riskin, J. (2002). *Science in the age of sensibility: The sentimental empiricists of the French enlightenment*. University of Chicago Press. 345 pp.
- Robins, N. (2012). The corporation that changed the world: How the East India company shaped the modern multinational. *Asian Affairs*, 43(1), 12-26. doi:
10.1080/03068374.2012.642512
- Rossini, P. M., Micera, S., Benvenuto, A., Carpaneto, J., Cavallo, G., Citi, L., ... & Ferreri, F. (2010). Double nerve intraneural interface implant on a human amputee for robotic hand control. *Clinical Neurophysiology*, 121(5), 777-783. doi:
10.1016/j.clinph.2010.01.001
- Rowland, F. S. (1990). Stratospheric ozone depletion by chlorofluorocarbons. *Ambio*, 19(6/7), 281-292. Retrieved from <http://www.jstor.org/stable/4313719>

- Rowland, F. S. (2008). Global warming and climate change. California State University Long Beach. [public lecture].
- Russell, B. A. (2012, January). *Minimum qualifications for faculty and administrators in California Community Colleges*. Sacramento, California, USA: Chancellor's Office, California Community Colleges, 82 p. Retrieved from http://www.sdccd.edu/docs/employment/minimum_quals.pdf
- Sano, F., Okamoto, T., Winarno, I., Hata, Y., & Ishida, Y. (2016). A cyber attack-resilient server inspired by biological diversity. *Artificial Life and Robotics*, 21(3), 345-350. doi: 10.1007/s10015-016-0286-5
- Sawyer, J. S. (1972). Man-made carbon dioxide and the “greenhouse” effect. *Nature*, 239(5366), 2. Retrieved from http://www.fas.harvard.edu/~eps5/writing_assignment/CLIMATE_BKGD/Sawyer_Nature_1972.pdf
- Scarborough, J. (1982). Beans, Pythagoras, taboos, and ancient dietetics. *The Classical World*, 75(6), 355-358. doi: 10.2307/4349404
- Scheffer, M., Brovkin, V., & Cox, P. M. (2006). Positive feedback between global warming and atmospheric CO₂ concentration inferred from past climate change. *Geophysical Research Letters*, 33(10), L10702. doi: 10.1029/2005GL025044
- scholar.google.com (2016). Google scholar. Retrieved from <https://scholar.google.com>
- Séralini, G. E., Mesnage, R., Defarge, N., Gress, S., Hennequin, D., Clair, E., ... & de Vendômois, J. S. (2013). Answers to critics: Why there is a long term toxicity due to a Roundup-tolerant genetically modified maize and to a Roundup herbicide. *Food and Chemical Toxicology*, 53, 476-483. doi: 10.1016/j.fct.2012.11.007

- Séralini, G. E., Clair, E., Mesnage, R., Gress, S., Defarge, N., Malatesta, M., ... & de Vendômois, J. S. (2014). Republished study: Long-term toxicity of a Roundup herbicide and a Roundup-tolerant genetically modified maize. *Environmental Sciences Europe*, 26(1), 1. doi: 10.1186/s12302-014-0014-5
- Shademan, A., Decker, R. S., Opfermann, J. D., Leonard, S., Krieger, A., & Kim, P. C. (2016). Supervised autonomous robotic soft tissue surgery. *Science Translational Medicine*, 8(337), 337ra64-337ra64. doi: 10.1126/scitranslmed.aad9398
- Sheldon, I. M. (2002). Regulation of biotechnology: Will we ever ‘freely’ trade GMOs? *European Review of Agricultural Economics*, 29(1), 155-176. doi: 10.1093/erae/29.1.155
- Slaper, H., Velders, G. J., Daniel, J. S., de Gruijl, F. R., & van der Leun, J. C. (1996). Estimates of ozone depletion and skin cancer incidence to examine the Vienna Convention achievements. *Nature*, 384(6606), 256-258. doi: 10.1038/384256a0
- Smiers, J. (2000). The abolition of copyright: Better for artists, third world countries and the public domain. *International Communication Gazette*, 62(5), 379-406. doi: 10.1177/0016549200062005003
- Solomon, S., Garcia, R. R., Rowland, F. S., & Wuebbles, D. J. (1986). On the depletion of Antarctic ozone. *Nature*, 321(6072), 755-758. doi: 10.1038/321755a0
- Solomon, S., Plattner, G. K., Knutti, R., & Friedlingstein, P. (2009). Irreversible climate change due to carbon dioxide emissions. *Proceedings of the National Academy of Sciences*, 106(6), 1704–1709, doi: 10.1073/pnas.0812721106
- Spash, C. L. (1993). Economics, ethics, and long-term environmental damages. *Environmental Ethics*, 15(2), 117-132. doi: 10.5840/enviroethics199315227

- Springmann, M., Godfray, H. C. J., Rayner, M., & Scarborough, P. (2016). Analysis and valuation of the health and climate change cobenefits of dietary change. *Proceedings of the National Academy of Sciences*, 113(15), 4146-4151. doi: 10.1073/pnas.1523119113
- Stocker, M. (1969). Consequentialism and its complexities. *American Philosophical Quarterly*, 6(4), 276-289. Retrieved from <http://www.jstor.org/stable/20009318>
- Stolarski, R. S., & Cicerone, R. J. (1974). Stratospheric chlorine: A possible sink for ozone. *Canadian Journal of Chemistry*, 52(8), 1610-1615. doi: 10.1139/v74-233
- Thapar, Romila. (1990). *A history of India, Volume 1*. Penguin UK. 384 pp.
- Thomas, R. (1995). Written in stone? Liberty, equality, orality and the codification of law. *Bulletin of the Institute of Classical Studies*, 40(1), 59-74. doi: 10.1111/j.2041-5370.1995.tb00464.x
- Tomasello, M., Savage-Rumbaugh, S., & Kruger, A. C. (1993). Imitative learning of actions on objects by children, chimpanzees, and enculturated chimpanzees. *Child Development*, 64(6), 1688-1705. doi: 10.1111/j.1467-8624.1993.tb04207.x
- Thoreau, H. D. (1854/1971) *Walden*. Princeton University Press. 368 pp.
- Tomasula, S. (2002). Genetic art and the aesthetics of biology. *Leonardo*, 35(2), 137-144. doi: 10.1162/00240940252940504
- Turkowski, P. (1990). Solvable Lie algebras of dimension six. *Journal of Mathematical Physics*, 31(6), 1344-1350. doi: 10.1063/1.528721
- Uzogara, S. G. (2000). The impact of genetic modification of human foods in the 21st century: A review. *Biotechnology Advances*, 18(3), 179-206. doi: 10.1016/S0734-9750(00)00033-1

- van der Dennen, J. M. G. (1998). The politics of peace in primitive societies: The adaptive rationale behind Corroboree and Calumet. In I. Eibl-Eibesfeldt and F. K. Salter (Eds.) *Indoctrinability, Ideology, and Warfare: Evolutionary Perspectives* (pp. 151-185). Oxford, New York: Berghahn Books.
- van Wees, H. (2016). Broadening the Scope: Thinking about Peace in the Pre-Modern World. In K. A. Raaflaub (Ed.) *Peace in the Ancient World: Concepts and Theories* (p. 158-180). Oxford: Wiley Blackwell.
- Varela, F. J., & Bourgine, P. (1992). *Toward a practice of autonomous systems: Proceedings of the first European conference on artificial life*. Cambridge, Massachusetts, USA: MIT Press. 534 pp.
- Velders, G. J., Andersen, S. O., Daniel, J. S., Fahey, D. W., & McFarland, M. (2007). The importance of the Montreal Protocol in protecting climate. *Proceedings of the National Academy of Sciences*, 104(12), 4814-4819. doi: 10.1073/pnas.0610328104
- Veloso, M. M., Biswas, J., Coltin, B., & Rosenthal, S. (2015, July). CoBots: Robust symbiotic autonomous mobile service robots. In *International Joint Conference on Artificial Intelligence* (p. 4423). Retrieved from <https://pdfs.semanticscholar.org/468d/43734488e0e29c3c11f2c15d9b1fb6f1adc4.pdf>
- Wagner, T., Heland, J., Zöger, M., & Platt, U. (2003). A fast H₂O total column density product from GOME-Validation with in-situ aircraft measurements. *Atmospheric Chemistry and Physics*, 3(3), 651-663. doi: 10.5194/acp-3-651-2003

Wang Ruo-yu. (2001). The harms and formation of the hole in the ozone layer and the necessary aid for it. *Journal of Henan University (Natural Science)*, 2001-2.

Retrieved from http://en.cnki.com.cn/Article_en/CJFDTOTAL-HDZR200102019.htm

Willigan, J. D., & Lynch, K. A. (1982). *Sources and methods of historical demography*. New York: Academic Press. 528 pp.

www.google.com (2016). Google. Retrieved from <https://www.google.com>

www.youtube.com (2016). YouTube. Retrieved from <https://www.youtube.com>

Wylic, A. (1999). Science, conservation, and stewardship: Evolving codes of conduct in archaeology. *Science and Engineering Ethics*, 5(3), 319-336. doi: 10.1007/s11948-999-0041-6

Zecca, M., Mizoguchi, Y., Endo, K., Iida, F., Kawabata, Y., Endo, N., ... & Takanishi, A. (2009, September). Whole body emotion expressions for KOBIAN humanoid robot—preliminary experiments with different Emotional patterns—. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on* (pp. 381-386). IEEE. doi: 10.1109/ROMAN.2009.5326184

APPENDIX A

GLOSSARY

aesthetics	The systematic study of perception and sensation.
astrobiology	The search for and study of non-terrestrial living organisms. The word is a compound of the terms <i>astronomy</i> and <i>biology</i> .
consequentialism	An ethical focus treating the effects of things as where value arises.
constructivism	A methodology that emphasizes how people construct knowledge themselves through the process of learning.
deontology	An ethical focus treating the innate qualities of things as where value arises.
ethics	A system of rules for behavior based on theory.
ethics of care	An ethical perspective wherein caring for the most vulnerable in a group is seen as important.
evolutionary ethics	An ethical perspective that looks at the evolutionary basis of behaviors. Also called <i>Social Darwinism</i> historically.
exobiology	The search for and study of non-terrestrial living organisms.
induction	Reasoning based on inferences using available evidence.
Kantian ethics	An ethical perspective that follows the work of Immanuel Kant, and whose primary feature is the <i>categorical imperative</i> —that people ought to act in a way that their actions can be taken as a universal maxim.
land ethics	An ethical perspective that promotes ecological conservation through a sense of kinship with the land.
metric	A feature that can be measured.
pedagogy	The systematic study of learning and instruction.
pragmatism	An ethical perspective wherein the effects of things are analyzed so as to improve practices and technology.
psychometric analysis	The study of personality features based on data that can be measured.
synthetic biology	The use of novel, artificially created molecules in biochemical settings, for example using new nucleobases to make additional DNA-analogs.
utilitarianism	An ethical perspective wherein actions are measured by their effects and optimized for the greatest good for the greatest number of people.

APPENDIX B

CONTACT LETTER, INFORMATION ABOUT THE
RESEARCH, FAQs, AND CONSENT FORM

EMAIL CONTACT LETTER

Good wishes for the day, and thank you so much for your time. We met (or may have met) during XXX. I am conducting qualitative research on attitudes towards living organisms in two academic communities: astrobiology, and the machine learning / artificial life / computational intelligence branch of computer science. My aim is to help these two communities share information while at the same time explore ethical considerations that reflect the current attitudes of researchers in these fields. The research will form the basis of my doctoral dissertation.

The research you are being asked to participate in is in the form of a questionnaire that has open-ended questions, taking from 10-40 minutes to complete, depending on your passion for the questions; and also, if desired, (at a later date) an online video group discussion on the topic, taking approximately 45-60 minutes. Participants can opt for one or either.

If you are interested in participating in the questionnaire, click this link.
XXX

If you are interested in participating in one of the online video group discussions, either add your email to the end of the questionnaire (link above) or reply to this email and indicate that you would like to participate in one of the video discussion groups.

Thank you so much for your time and interest!

Sincerely,
Daniel Helman
Doctoral Student, Sustainability Education
Prescott College

INFORMATION ABOUT THE RESEARCH

You are being invited to take part in a research study. Taking part is voluntary. Before you decide whether to take part I would like you to understand why the research is being done and what it would involve for you. Please e-mail me if there is anything that is not clear or that you are unsure of before taking part in this survey.

Purpose of the Study - This research study explores the experiences of astrobiologists and machine learning / artificial life / computational intelligence computer scientists in a brief, informal way to give participants a chance to reflect on their own professional goals and experiences and to share in the experiences of their colleagues addressing some of the same topics, both (1) to further research, and also (2) to gather data to develop ethical considerations related to organisms based on what already is a professional outlook, and also (3) to develop policy recommendations based on the considerations found, plus (4) to develop a few lesson plans for teaching aspects of astrobiology or computer science related to machine learning / artificial life / computational intelligence in classrooms. The process is meant to be of personal benefit to the participants and of service to these research fields.

FAQ

Why have I been invited? I am aiming to recruit about 150 participants from the population of academics and researchers involved in either astrobiology or in the branches of computer science that deal with machine learning, artificial life or computational intelligence.

Do I have to take part? It is up to you to decide whether to take part in the research. If you agree to take part, you will be asked to sign a consent form. You are free to withdraw at any time, without giving a reason.

What will happen to me if I take part? You will be asked to give informed consent to take part in the study. If you give consent, you will be asked to complete an online questionnaire. This questionnaire should take no more than 10-40 minutes to complete depending on your passion with the subject. You will also be asked whether you wish to participate in an optional, additional part of the study—video group discussions on the topic. The video group discussions are meant to last approximately 45-60 minutes. These will be scheduled to work around participants' other needs.

What will happen if I don't want to carry on with the study? You can withdraw from the study at any time. If you choose to withdraw you can contact Daniel Helman (see below). Any information that you provide during the study will be destroyed if you choose to withdraw up until 15 January 2017. If you choose to withdraw after this date then your data for the analysis will be included but all

identifiable information (including the original questionnaire data) will be destroyed.

Will my taking part in this study be kept confidential? You need not give your name and institutional affiliation to participate in this study. You will instead be identified by a number, for example, Participant Number 1. Your information from your completed questionnaires will be kept on computer files that will be posted to an online depository and available to the public.

Expenses and payments. There is no compensation provided for participating in this study. Participation should be based on personal and professional interest.

Risks or benefits of taking part. Taking part in this research study may benefit you as reflecting on thoughts and feelings related to your research may be informative. There are no known risks of taking part in this study. The researcher will be available to answer any questions about the research until 15 April 2017 by the contact details provided.

What will happen to the results of the study? Any information you give the researcher may be put into a doctoral dissertation and associated research articles, and the researcher will attempt to have the latter published in research journals. If you e-mail the researcher and so request, your results will be made available to you if you would like to add or veto information.

Who is organizing and funding this research? This research is organized by Prescott College, specifically the doctoral program in sustainability education. There was no funding provided for this research. It was self-funded.

Who has reviewed the study? This study has been approved by a Prescott College Institutional Review Board (IRB). For full details regarding the research supervisors and IRB please see below.

Further Information and contact details–

Lead Researcher: Daniel S. Helman, Sustainability Education, Prescott College.
E-mail: daniel.helman@student.prescott.edu

Dissertation Supervisor: Dr. Pramod Parajuli, Sustainability Education, Prescott College.
E-mail: pparajuli@prescott.edu

If you are unhappy with the study for any reason you can make a complaint to either of the above researchers.

** In addition, if you have any suggestions or comments about the questionnaire, please do not hesitate to contact the lead researcher.

CONSENT FORM

To participate in this study it is required for you to consent to all of the conditions below:

- 1) I confirm that I have read and understood the information for the above study within the information sheet.
- 2) I understand that my participation is voluntary and that I am free to withdraw my data from the manuscript or from any subsequent housing of the study data without giving any reason.
- 3) I understand that if I withdraw from the study the data collected up to that point will be destroyed if I desire.
- 4) I understand that any information I provide will be kept confidential if I indicate that I wish it to be confidential.
- 5) I agree to take part in this Study.

APPENDIX C

QUESTIONNAIRE AND GROUP DISCUSSION QUESTIONS

QUESTIONNAIRE

This questionnaire consists of a series of twelve questions, divided into four sets of three questions each. It is designed to elicit helpful information related to your professional work as a researcher or in innovation. The process of the questionnaire is meant to assist you in considering your own work and move it forward. Feel free to write as much or as little as you like.

The following three questions are related to your profession.

- Q1. Please take a moment to reflect upon your professional life. What led you to the work that you do?
- Q2. Please describe some questions that you are working on right now in your research and innovation. What research questions interest you?
- Q3. Please describe a little about your philosophy towards your work. Is your approach scientific? What is a scientific approach to research and innovation?

The following three questions are related to defining the concept life. They explore what constitutes an organism or a living system.

- Q4. Does any of your research use a definition of a living organism or a living system? If yes, please describe how a definition is used.
- Q5. Are there any research areas that you imagine might benefit from a definition for living organism or system? If so, please describe how you imagine a definition might benefit the work.
- Q6. Are there any research areas that you imagine might be hindered by having a definition of living organism or living system? If so, please describe how you imagine a definition might hinder progress.

The following three questions are related to ethical frameworks, that is, conceptions of principles guiding beneficial actions.

- Q7. What is your general opinion of ethical frameworks? Are they important? Are they valid?
- Q8. In your field of research, what role do you see ethics playing, if any?
- Q9. Do you have any recommendations regarding ethical frameworks as they relate to work fifty years from now? If so, please describe them.

The following three questions are related to personal information and feedback.

Q10. So that your answers may be placed in context, you may enter your name and affiliation here, or just your name, or just your affiliation, as it suits you. You may also leave this question blank if you wish your answers to be anonymous.

Q11. What is your field of research or innovation?

Q12. Please take a moment and consider what you've written since the beginning of the questionnaire. What was your experience of taking this questionnaire? Did you find the experience useful? Please type any additional comments here.

Video Group Discussions

- Would you be willing to participate in a video group discussion with colleagues focused on these and similar questions? The video group discussions are meant to last approximately 45-60 minutes. These will be scheduled to work around participants' other needs and will use a video platform such as Skype. (Please type your email address here if you are interested.)

This concludes the questionnaire. Thank you so very much!

GROUP DISCUSSION QUESTIONS

From the questionnaire:*Profession*

What led you to the work that you do?

What research questions interest you?

Is your approach to research and innovation scientific?

What is a scientific approach to research and innovation?

Life definitions

Does any of your research use a definition of living organism or a living system?

If yes, how is a definition is used?

Are there any research areas that you imagine might benefit from a definition of living organism or living system?

If so, how do you imagine a definition might benefit the work?

Are there any research areas that you imagine might be hindered by having a definition of living organism or living system?

If so, how do you imagine a definition might hinder progress?

Ethics

What is your general opinion of ethical frameworks?

Are they important?

Are they valid?

In your field of research, what role do you see ethics playing, if any?

Do you have any recommendations regarding ethical frameworks as they relate to work fifty years from now?

Questionnaire

What was your experience of taking this questionnaire?

Did you find the experience useful?

Additional questions:*General*

Does anyone want to start us off with some comments?

Does anyone have any new ideas to add to the discussion?

What did you think of the questionnaire?

Profession

Could you share a little of what you are excited about in your work?

What do you think of the progress that's been made in your field recently? (And please state what your field is.)

What do you attribute the progress in your field to?

Is it correct to think that your field is on the verge of a major breakthrough?

What do you see as your greatest need as a researcher or innovator?

Where do you go when you need some inspiration?
How do you get funding for your work?
How could you be more successful to get funding?
Would you recommend other researchers switch to your field?
Would you recommend young adults to go into your field?

Computers

What is the role of machine learning in your work?
What is the role of artificial intelligence in your work?
How pervasive is machine learning in the world?
What decisions are typically made using machine learning?
What are some areas of human endeavor that are obviously better off because of machine learning algorithms?
How do you see computer architecture changing in the next 50 years and how will this impact your research field?
Does your research or innovation change peoples' ideas of what computers are capable of?

Science

Do you see the scientific method continuing to evolve?
Is it static in time?
Do you see science as a respectful pursuit?
What falls outside the realm of science?
What do you see as some limits to your work?

Life definitions

Do you think that computer viruses ought to be classed as living organisms?
Do you think that viruses ought to be classed as living organisms?
Do you think that quantum computing will make much difference in artificial intelligence systems?
Do you think that a plausible setting for an abiogenic origin of life has been proposed in the scientific literature?
Is origin of life a misnomer? What is meant by life?
Do you think there ought to be a definition for life maintained by a scientific body in the same way that the SI units are maintained by the International Bureau of Weights and Measures?
Do you see much crossover between astrobiology and computer science?
Is life an unscientific quality, akin to caloric?
Can life or *degree of aliveness* be measured?
What defines a living system?
Must life be based on chemistry, i.e., chemical life forms?
People with computer-aided prostheses are obviously living. How little of a person could be left and still call them a living organism?
What is the role of memory in living organisms?
What is the role of memory in intelligence?
What is the role of memory in a physical state?

What is the role of memory in a computational system?
Why are artificial life systems researchers not making more progress?
What do you see as fundamental difficulties in creating artificial life?
What do you see as fundamental difficulties in creating artificial intelligence?
What do you see as fundamental difficulties in finding life beyond Earth?
What do you make of the concept life?
Is it a scientific concept?
Does your research or innovation change people's ideas of what life is? Could it?
Does your research or innovation change people's ideas of what living organisms are? Could it?
Does your research or innovation change people's ideas of what intelligence is? Could it?
Does your research or innovation change people's ideas of what thought is? Could it?

Ethics

Do you see values and ethics as important in your work or how it is used?
Do you see human ethics continuing to evolve?
What do you make of ethics?
What are your thoughts about utilitarianism?
Which is more important: intrinsic value or utilitarianism?
Is your work important intrinsically?
Is your work important extrinsically, i.e., is it externally useful?
What are your thoughts about an ethics of virtue?
What are your thoughts about consequentialism?
What are your thoughts about deontology, ethical systems based on duty?
How do you reconcile intrinsic and extrinsic values?
How might you differentiate intrinsic values?
Are intrinsic and extrinsic values equal?

APPENDIX D
QUESTIONNAIRE RESPONSES

Responses from:

Questionnaire: Research Interests & Ethical Issues

Astrobiologists and (Machine Learning / Artificial Life / Computational Intelligence) Computer Scientists and Affiliated Professions

The text of the follow-up email that was sent out to respondents who had provided their contact information as part of the questionnaire is reproduced here:

The results of this questionnaire are presented below in their original form, but with names or other identifying information not included. In total 29 people participated and the responses were useful, moving and informative. Note that each individual response is presented as a new paragraph, except where a response spans more than one paragraph of text. In that instance, the response is enclosed in quotation marks, and quotation marks within the answer have been changed to conform with punctuation mark conventions.

Please direct any questions related to this questionnaire and the work related to it to Daniel S. Helman, Sustainability Education, Prescott College.

daniel.helman@student.prescott.edu

Thank you so much for your time and for the work that you do!

[Venice, California, USA. 25 January 2017.]

Q1. Please take a moment to reflect upon your professional life. What led you to the work that you do?

Curiosity

I became interested in philosophy at some point in high school. After reading a bit here and there I came to the conclusion that without understanding space and time I won't get further. So I studied physics. I studied some AI, robotics, and neuroscience on the side and at some point realized that I won't make it in string theory. So I asked myself what would I do if I already knew the end result of string theory, the grand unified theory. I thought I would want to find out what life is. So that is what I do now.

THIS IS NOT MY WORK. IT IS MY HOBBY. I DO IT BECAUSE I AM REALLY INTERESTED IN WHETHER THERE IS LIFE ON MARS.

[Send me a note and I will send along the link written here after having gotten the ok from the questionnaire respondent.]

A passion for science going back to six years of age. Endless curiosity.

It was my original intention to become a medical doctor, and I prepared for such throughout high school and college. During my senior year of college, I decided that a career in medicine wasn't for me, so I instead entered grad school to study astrobiology and the origin of life; subjects which piqued my interest at the time (and still do).

I wanted to perform interesting work. I also wanted to expand human knowledge.

This is a difficult question to answer, because I took a long and winding route towards what I do, while at the same time, in retrospect, I was drawn towards it from quite early on. I began by signing up for a degree in theoretical physics because I knew I wanted to answer deep and fundamental questions. However, for practical reasons I switched to a computer science degree part way through. My interest in evolution was sparked by studying genetic algorithms in that degree. My career since then, while varied, has always focused on using techniques from computer science, mathematics and physics to gain fundamental insights into the nature of the living world.

serendipity, extraordinary (unrepeatable) luck, help from others and general puzzlement over the workings of human groups and the Universe

I got interested in geology as undergrad. I found the slow tectonics of the continental interior where I lived interesting. I became involved in the start of plate tectonics in graduate school. I became involved in planets after Apollo had ended. I was on NRC committee in late 1980s. Question of large asteroid impact on early earth and life came up. Since then I have been involved with that and with physical conditions on early earth and planets with respect to life.

Q1. Please take a moment to reflect upon your professional life. What led you to the work that you do?

The enjoyment of research, and answering new questions

Basically, it was always clear for me that I wanted to become a natural scientist, from early childhood days on, so I hardly ever considered alternatives. Later on, as an undergraduate/graduate student, I just read books or papers, as many as I could, did internships in fields that I thought were the most interesting, and that "strategy" more or less directly took me to the work I am still doing today.

Kids' science books in a public library. I decided to be a scientist by age 10.

A passion for solving problems, and understanding things. AI and Intelligence fits well.

My current work has three origins: (1) my fascination with computers from an early age, (2) my desire to understand how we learn (as humans, as scientists) how the world works, (3) my desire to have a positive impact on humanity.

Interest in helping the planet; trust in logically consistent solutions

dissatisfaction with the knowledge base of clinical neurology

I have always been interested in what makes life different than non-life. It was always the biggest question in my mind and much more interesting than any of the other subjects/questions. Growing up, I always became bored with everything very quickly. Physics and science was the only think that remained interesting after many hours of exploration.

I've always been interested in (1) getting computers to do cool things and (2) understanding people and the kinds of decisions they make. My work brings these two threads together.

An interest in how to build intelligent machines going back to early childhood.

I am an anthropologist, with a specialty in prehistoric archaeology and cultural evolution. However I studied biology as an undergraduate and have always been interested in how biology, especially evolution, relates to the broader questions of meaning, purpose and other elements of humanity. I have not done actual research in origins of life or the other specialties mentioned, but I am now involved in research support grantmaking in this area, so naturally have given it some thought, met a number of people and so on.

I was interested in intelligence in general and specially in the the challenge of creating machines able to think.

I have been fascinated with numbers and computers since early childhood. I began working professionally as a computer programmer over 50 years ago. After graduate

Q1. Please take a moment to reflect upon your professional life. What led you to the work that you do?

school, I worked at [technology company] on the problem of speech recognition (making a computer type what a human being is saying) and machine translation (making a computer translate some thing that has been typed in one human language into something that is typed in another human language). Success in these two problems hinges, among other things, on the ability to predict what is coming next in a English sentence given what has already appeared in the sentence. One of my colleagues and I approach the people running the investments of the [technology company] pension fund with the proposal that we could use our skills to predict future prices of financial instruments and thereby help with the management of [technology company]'s pension investments. [Technology company] was not interested in our idea, so we joined a financial company where I have worked ever since.

Some combination of active parenting and fortuitous events over which I had no control. My parents always emphasized mathematics as a key subject in my schooling, and my father pushed me towards a career in engineering. After realizing I enjoyed the physics "behind" the engineering much more than the application "within" engineering, I changed the emphasis of my studies to physics and mathematics, and decided to attend graduate school. While a graduate student, and after failing to connect with several potential advisors in my home department, a new faculty hire arrived whose interests in exoplanets and astrobiology were perfectly aligned with my own. My studies in planetary atmospheres, habitability, and biosignatures would never have been if not for my advisor arriving when she did at the right stage of my graduate career.

If I describe it in a nutshell, it comes down to: 1) my motivation for the topic 2) my belief in my abilities as a scientist 3) my faith in the field

Interest in understanding how life started and how chemical reactions lead to consciousness.

I was interested in the question of the origin of life since I was a teenager, from walks in nature and studying how plants grow. I entered computer science in part to be able to simulate nature and emergence in systems.

curiosity and passion

My academic curiosity was first ignited as a child sifting through Devonian fossil beds in Pennsylvania in the company of my father and sister. As I held fossil corals and trilobites in my hands, turning them over, I began to imagine the world in which the creatures that created these casts inhabited. A world far different from our own, though it occupied the same physical space. That imagining of worlds different from ours was joined with curiosity about astronomy and physics later in my schooling (middle school and high school). The characterization and modeling of exoplanet planetary systems takes the mind to most exotic locales in the universe where nonetheless a person may imagine themselves standing and observing. I wanted to understand what kinds of worlds and

Q1. Please take a moment to reflect upon your professional life. What led you to the work that you do?

places are out there and science provides the framework to do that. Most critically, I wanted to contribute to our understanding of these places, potentially in the search for life elsewhere, and be able to relate this information to other curious individuals.

Q2. Please describe some questions you are working on right now in your research and innovation. What research questions interest you?

redefining origins of life

I want to find out how a dynamical system can contain something that justifiably can be called an agent. I.e. a thing that is individualized, can "act", and has some kind of goal-directedness. Since for a dynamical system the dynamical law determines everything that is going on within it, it seems paradoxical that within such a system something could exist that can perform its own actions and has its own goals. I try to formally define notions of individuals, actions, and goal-directedness which "make sense" and can occur within dynamical systems.

WHAT ARE THE IDENTIFYING MINERALS THAT MAKE UP CREDIBLE ORIGIN OF LIFE THEORIES ON EARTH OR MARS.

I'm Emeritus at UC Santa Barbara and living in the SF Bay Area. My questions are prompted by reading Science, Nature, and the society bulletins that come to my mailbox. I'm working on the idea the the spaces between mica sheets are an excellent place for the origins of life. My latest insight[?] is that organelles without membranes are a more likely place for life's origins than fragile membrane-enclosed organelles. My work is all 'armchair' or 'theoretical', except for occasional kitchen-counter experiments with mica. My work expands beyond mica origins to encompass anything about the origins of life that interests me and seems novel; thus far, everything I think of 'fits' nicely between Muscovite mica sheets.

How can life begin on Earth and other habitable planets?

Can thermodynamics help predict relative abundances of various biomolecules synthesized by life? Can we characterize the balance of "function" and "cost" of biomolecules depending on the environment inhabited by an organism? How has this balance affected the course of life's evolution?

"1) I am exploring the origin of the interstellar medium

2) I am enquiring about the transition from Darwinian biological life to physical intelligent life.

3) I am also interested in the history of science."

"Is the emergence of life (at least in part) the result of an underlying principle, and if so what principle?

What are the necessary and sufficient conditions for evolution to emerge in a physical system?

Were the first forms of life chemically similar to modern-day life, in terms of being

Q2. Please describe some questions you are working on right now in your research and innovation. What research questions interest you?

constructed from amino acids and/or nucleotides, or should we expect them to have been based on a different chemistry, with the modern biochemistry arising later as the result of evolution?

What, in general, are the properties of complex chemical networks out of equilibrium? Is it possible under appropriate circumstances for a 'messy' chemical system to become a complex one? (Here I use 'messy' to mean a chemistry like Miller-Urey chemistry or Formose that produces a huge diversity of products. By 'complex' I mean one that's qualitatively more similar to the chemistry of a cell, particularly in the sense of having a more 'sparse' network of reactions that's controlled by highly specific catalysts.)

Is it possible to observe, in a chemistry lab, the emergence of a complex self-producing and self-maintaining system other than life, from a system that initially lacks such complexity?

Is there a 'Moore's law' for evolution? I.e. under appropriate circumstances, can a biological species accumulate adaptations at an exponentially accelerating rate?"

How did life emerge - a whole gamut of questions

Nonlinear seismology and ground damage from strong shaking. Large impacts maintain ground porosity and permeability on smaller objects with weak tectonics. I am also still working on CO₂ dominated arc volcanics as site for early life on the Earth.

Mechanisms of electricity production and use by bacteria, and ability of microbes to live in extreme conditions of low nutrients and high pH

My work is largely centered around redox biochemistry. From that point, topics branch out, in more directions than I can handle. Redox processes are relevant for many diseases, this was my starting point in the beginning, but also for the structure of the cell, both modern and primordial. In the end, I came to believe that many aspects of the evolution of life, on almost every level, are due to redox chemical demands. Still, this topic only plays a minor role in current thinking, which I believe will change in the years to come.

I'm a polyglot. 1) Is embryogenesis a branching, goal seeking process? 2) Were the first protocells structured? 3) How do we optimally do a mapping of lines to a single point on the line for positron emission tomography? 4) How do we build Diafuel (diatom biofuel) solar panels for local production of gasoline? 5) How do diatoms build their shells? 6) How do diatoms move?

How AI can reuse learning in large scale and related problems

How can AI be applied to help solve difficult sustainability problems especially in biological conservation and ecosystem management? How can AI be applied to improve

Q2. Please describe some questions you are working on right now in your research and innovation. What research questions interest you?

agricultural productivity in developing countries? How can machine learning systems be made robust to "unknown unknowns"; to unanticipated aspects of the world?

big data approaches to assessing soil health

critical factors governing neural plasticity after injury to the brain or spinal cord

I want to know what makes life different than non-life. How can I use this knowledge to improve computers? How are computers and living systems related? Can computers become alive?

How can machines learn from benevolent teachers? How can machines form rich hierarchies of knowledge to inform their interactions with the world?

How to learn sensori-motor representations of the world in an unsupervised manner without the content of those representations (meanings) being parasitic on the meanings in the heads of humans.

In the areas relevant to this survey, I am deeply interested in the question of what life is - not necessarily to take a definitional approach to pin it down that way, but in the sense of the boundaries - what is "inanimate" matter capable of that we have not previously known, and in what ways are living things different. I am also interested in the processes of evolution, especially those often categorized as "the extended synthesis" and how they relate to humans - thus questions like how do cultural differences and physical phenotypic plasticity or niche construction relate in the human (and other cultural animals)?

I work on autonomous systems. I'm interested in machines able to self-perceive, self-reflect and self-act in order to perform better their duties.

The nature of my work does not allow me to answer this question.

I am broadly interested in the remote characterization of planetary and exoplanetary atmospheres. Currently, I am working to understand how clouds impact transit spectra of exoplanets, and am also trying to understand how reflected light observations of terrestrial exoplanets can be used to characterize these worlds for habitability and life.

Some questions that come to mind are: 1) Is there a direct connection between the chemistry in cold dark regions of space and life on Earth? 2) Are the conditions for life only present on Earth or can the conditions exist elsewhere in this vast Universe?

How do you go from an racemic mixture of chemicals (amino acids or sugars) to the homochiral systems employed by biology? What kinds of organic molecules made up the

Q2. Please describe some questions you are working on right now in your research and innovation. What research questions interest you?

prebiotic soup on the early Earth?

I am primarily focused on the development and testing of a new hypothesis and full model for the origin of life working with [a scientist] at [university] and many other colleagues. I am also interested in the development of sustainable spaceflight having developed numerous designs for spacecraft and recently the [project] design for handling and harvesting resources from asteroids.

understanding the components, interactions, dimensions, structures, processes, development, genetics, and evolution of the human mind

How would we recognize the remotely-detectable signs of life on a habitable exoplanet? What can we do to mitigate against the potential for “false positive” detections? How common are planetary biospheres like Earth, and what is their distribution in the solar neighborhood? As currently our only example of a habitable and inhabited planets, how has Earth’s spectral character evolved with geologic time? How good of an analogy does Earth provide in the search for life outside the solar system? What can prospective modeling of exoplanet atmosphere do for setting the instrument requirements for robustly detecting life outside the solar system?

Q3. Please describe a little about your philosophy towards your work. Is your approach scientific? What is a scientific approach to research and innovation?

Asian philosophy, the answer is in front of you

"I think my approach is scientific. I work hard to define all concepts rigorously and within established mathematical frameworks. I also test the concepts with computer simulations which simply would not work if the concepts were not logically consistent. This means I do not get to choose the concepts and their relations freely but am instead constrained and guided by logic. I think this is the essential aspect of science (I prefer the German term *Wissenschaft*, which means knowledge production, science is often restricted to natural science and my field (artificial life) is not really part of that) that the practitioner has to subject his concepts to an "external" or at least from the perspective of the practitioner immutable arbitration. In the natural sciences this means we have to predict experimental outcomes which we don't get to choose ourselves which are instead results of the laws of physics. The experimental results will not change just because our theory predicts something else. In mathematics and also computer science and artificial life, logic is the external arbiter, in a way. We can not choose our theorems freely, we have to prove them, and if they are wrong there is no prove however much we would like it. We can also not tell a computer to do something that is logically inconsistent, it won't do it. Research is only research if the practitioner is forced to search and cannot just make everything up as they go along. What counts as a finding must be restricted in some manner be it by the laws of logic or those of physics. Or actually since the past is immutable a historian is also a researcher in this sense.

I cannot directly test my theories in the real world because we can never measure enough about the universe to use my theory and even if we could we still would not be able to calculate the involved quantities. They are practically uncomputable. Maybe in the future we will come up with some good approximations which would be great. However, I am interested in finding out how (and whether) a concept of life can be constructed in a way that is consistent with physics (in the form of dynamical systems theory). This may be checked with logic/mathematics. Whether we can then apply the insights gained in any way other than philosophically is secondary for me even if it might be necessary to allow me an actual career in science.

Innovation, I don't really think about it much. I guess innovation is somehow the creation of artifacts, it is not the same as research because research tries to find out what is (or was) going on. Whereas innovation tries to create something that wasn't there before, well before the researcher found out something this knowledge wasn't there before either so research is always innovation in some sense. I'll pass on innovation it would require some thinking."

MY WORK IS NOT SCIENTIFIC BECAUSE I DON'T DO EXPERIMENTS. I READ THE LITERATURE AND DESIGN EXHIBITS TO BE SHOWN AT SCIENTIFIC CONFERENCES.

My research is curiosity-driven, not driven specifically by the Scientific Method. But it

Q3. Please describe a little about your philosophy towards your work. Is your approach scientific? What is a scientific approach to research and innovation?

does start with questions, like the Scientific Method. My approach is Scientific, because it is tested by investigating the published literature to see whether my ideas are reasonable, based on what has been published and therefore shown to be feasible in chemistry and other areas of science. The published work is not on the origins of life but on chemistry and biochemistry and cell biology and biophysics in general.

Purely scientific. I'm an experimentalist who tests alternative hypotheses.

I suppose my approach is scientific, in that I try to prove my hypotheses wrong in any way I can. If I am unsuccessful, then I know I might be on to something.

I ask many questions, and when there are no answers, it generally means that I am examining an area between disciplines. So then I try to answer the questions myself.

"I certainly believe my work is scientific, yes. This is almost by definition, since I think the only reasonable definition of science is 'what scientists do', and I am currently employed as a scientist. (Which is not to say that one could not take a scientific approach if not employed as a scientist - it's an 'if' rather than an 'if and only if'.)

I'm not sure how to address the question of 'what is a scientific approach to research and innovation?' I suppose the word 'scientific' has connotations of being methodical, of using reasoned arguments, of seeking evidence, and of changing one's mind when the evidence demands it. (For others it may also have connotations of logical positivism or other formalised versions of the scientific method. For me that kind of view is too restrictive.)

As for my philosophy towards my work, I would say that the origin of life is a rather difficult thing to study scientifically, since we currently have neither a widely accepted theory nor really any evidence to work with at all. Many researchers have very strong opinions about the origin of life, and they usually have experimental data to support those opinions - but those people do not on the whole agree with one another even on the broadest points, and the data is not generally of the kind that could be used to distinguish one origins scenario from another. My personal philosophy is that I don't want to devote my career to only one of these possible stories about the origin of life. Because of this, I concentrate on the search for underlying principles that are as 'scenario-independent' as possible. These should end up being useful regardless of what the specific historical contingencies turn out to have been."

"I can't do better than quote Steven Shapin, 'Michael Polanyi's idea of "tacit knowledge" in The London Review of Books (15th December 2011): (Polanyi, M. 1962. Personal knowledge: Towards a post-critical philosophy. Psychology Press): 'Science is a vast fiduciary system. Scientists know what they do by finding trustworthy sources and then trusting them. It is also what Polanyi called a polycentric system, in which autonomous and only loosely coordinated groups of specialists—mildly skeptical and mainly trusting—periodically keep an eye out for what is going on next door. The coherence and

Q3. Please describe a little about your philosophy towards your work. Is your approach scientific? What is a scientific approach to research and innovation?

integrity of the body of scientific knowledge arise through these processes of mutual adjustment. Finally the bases of scientific judgment cannot be completely articulated because the "tacit" dimension is ineliminable. It is not a fly in the formal ointment; it is what makes science science. You would understand that, Polanyi suggested, if you knew what it was like to be "confronted with the anxious dilemma of a live scientific issue". The further away you are from the quotidian life of scientific practice, the more you tend to be infatuated with myths of method."

I do attempt to use the scientific method. Like looking for platinum, once must think broadly but then carefully appraise ideas. There needs to be some grabbing at straws.

My philosophy is that research should be aimed at answering new questions for which answers are not presently available -- trying to understand how life works in places where things are so extreme or different that we don't understand now. Also, keeping one's eyes open for things that don't fit the present paradigm(s), which of course, are not always correct.

"I would describe myself as someone playing a puzzle. The pieces are out there, but in many instances, there is no apparent logic visible, and everywhere are pairs of pieces that have been tentatively put together in the past, but which do not fit. So, the playing field is just out there.

What is worse, the pieces of several puzzles (e.g., one describing the physics, one the chemistry, one the biology of cellular life) have been mixed up, and some pieces belong to more than one puzzle. So I try to put the pieces together without knowing what puzzle they belong to (i.e., what the final image should be). Hence, 'seeing' patterns is the most important talent a (natural) scientist needs, in my view. The intention to be 'innovative' is totally irrelevant. I especially reject the idea that 'excellence' or 'innovation' can be planned: the questions come to the minds, not vice versa."

I have no idea. Try asking: Is there a mathematics of mathematics research? Seems an absurd question.

Hypothesis testing with statistical experimental analysis

My work consists of designing algorithms (and software frameworks), testing their effectiveness experimentally, and proving guarantees on their behavior mathematically. So it is a mix of empirical science and mathematical proof.

I aim to produce scientifically thorough results making use of big data.

ideally it draws from basic animal work and seeks to extrapolate to human illness

My approach is scientific, driven by personal curiosities. I ask questions based on what I

Q3. Please describe a little about your philosophy towards your work. Is your approach scientific? What is a scientific approach to research and innovation?

think is interesting. This obviously introduces a bias in the direction of my work, but I try my best to remove bias from the results. I'm not always perfect at this part, but I am aware that it could be an issue.

Lately, I've been saying that my philosophy is inspired by George Box:
https://en.wikipedia.org/wiki/All_models_are_wrong .

A scientific approach is one that seeks to answer questions in ways that are testable/falsifiable. Innovation, though, requires an approach to science that seeks to answer big questions, even if those answers require us to focus on small steps. The key is to keep the big questions in mind at all times.

These are great questions, but challenging. I am not a scientist and my approach to these questions is philosophical and anthropological in that I always seem drawn to wider implications - though they depend on scientific findings, as any philosophy must. In grantmaking, of course, I do need to understand the science well enough to appreciate a good question and I need to know enough people who can evaluate the methods proposed for answering a question. While I appreciate the growing value of simulations and related work, I still see the core of a scientific approach as being at some level an empirical investigation of the material world around us. Having more experience in the historical sciences, I don't think controlled experiments are essential, but careful hypothesis testing can take place in other ways and be just as empirical.

My philosophical standpoint is classical science -as understood in physics- and science-grounded technology. My approach is scientific; I work towards a scientific understanding of mind -a concept that transcend humans- and its implications in machine construction. A scientific approach is characterised by the use of a ground theory that is conceptually solid and grounded in experiments.

I do not see my work as an effort to understand the inner working of the universe. I do, however, see it as an effort to predict from what has already happened what is likely to happen next. I do not believe that at some point in my work I will suddenly realize that the future is at last entirely known. I do, however, believe that for the foreseeable future I will be able to do a better and better job of predicting what is going to happen next.

My work is curiosity-driven. I make progress by finding (what I hope to be) important gaps in our knowledge of exoplanets, and then working to fill these gaps. Seldom do I start with a well-defined "hypothesis" that I hope to test. Generally, I have a fairly loose definition of what constitutes a "scientific approach." If I had to write it down, I'd say something like, "the use of observations, models, and/or theory to expand or test our understanding of the laws that govern our Universe (and all the curious things contained within it)."

I would say it is a scientific approach. Some of the highlights of the scientific approach,

Q3. Please describe a little about your philosophy towards your work. Is your approach scientific? What is a scientific approach to research and innovation?

in my opinion, are: 1) remain unbiased about your work 2) data must be reproducible 3) control experiments are crucial to eliminating ideas and/or making a claim 4) pragmatic work

A scientific approach means working in a stepwise fashion to understand the laws and principles that cause specific results. It involves formulating hypotheses, and then working to refute those hypotheses until only the most robust explanations persist.

My approach is a combination of thought experiment, a creative imaginative seeing of complex systems and relationships, and laboratory and field testing. Working with David Deamer I engage in the combination of these systemic thought experiments and then the development of testable hypotheses which compete with alternative hypotheses in the field, as put forth by John Platt in his Science essay in 1964 "Strong Inference". I believe this a strong approach to science.

"I am trained theoretically as an evolutionary biologist, and practically as a naturalist studying beetles, ants, butterflies, and behavior of climbing plants in the lowland rainforests of Costa Rica. As a naturalist I have gone into one of the most complex ecosystems on Earth to make careful and patient observations to detect patterns in living nature. While focused on one pattern* I may stumble across other unrelated patterns and opportunistically explore them*. A haphazardly encountered pattern can develop into a major research program*. *[Contact me for references the respondent added here, and I will send them to you pending respondent approval.]

I bring this same style and sensibility to the study of the human mind. I believe that even today, in 2016, the mind remains a relatively unexplored wilderness as does much tropical rainforest. Given what I consider the primitive level of our understanding of mind, I believe that science is at the stage where the natural history approach can productively precede the application of more structured scientific methods. The natural history approach can generate hypotheses about the mind that can be productively tested with experimental scientific methods."

My approach is scientific in the sense that the processes in my simulations are physically validated. The motivation behind the research is backed more by curiosity than pure reasoning. Of course, the motivation behind any research area is backed by axiomatic boundary conditions that justify one area of focus over another.

Q4. Does any of your research use a definition of living organism or a living system? If yes, please describe how a definition is used.

Yes, the NASA one but still very incomplete

I am trying to come up with one. I do refer to other definitions and relate them to my own approach.

YES. I HAVE A REDUCTIONIST APPROACH THAT BOILS LIFE DOWN TO THE CONCEPT OF MEMORY (EITHER DNA/RNA OR COMPUTER) WHEN LIFE IS IN SUSPENDED ANIMATION.

My research doesn't depend on a definition of living organism. It regards the transition from non-living to living as being a gradual one, not an all-or-none transition from non-living to living. I like Addy Pross's book about the origin of life via dynamic kinetic systems. You can check this out, too. It was an invited response to an article defining the origins of life: Life = Self-Reproduction with Variations? [Author comment: Send me a note if you would like the article reference, and I will send it to you pending ok from the questionnaire respondent.]

Yes. Even the simplest life is incredibly complex, so there is no dictionary-style definition. Instead there is a set of properties that I try to establish and integrate in the laboratory, then test in the field.

Sort of. See below.

The universe can be considered as an exploration of methods of maintaining continuity (survival). Life consists of forms or systems which use positive feedback for survival. It seems likely that the only way that the universe can initiate these is through biochemistry. But when biology develops intelligence (nervous systems, motor organs and sensing) that intelligence can develop physical intelligent life. Because these can (and likely have already) operate in a much wider range of physical conditions than biological life, and can ""hibernate"" for thousands of years, they will be able to explore the universe and find better survival habitats as well as explore the full range of scientific questions, again so as to improve their survival continuity.

"Generally, I find that the focus on definitions has tended to hold the field back. (This is particularly true of the Artificial Life community but it holds for origins of life more broadly.) Some people are interested in the origins of metabolism and others are interested in the origins of evolution. These are both vitally important questions. Both are worthy of being addressed scientifically, and for me personally, I think it's unlikely that they can be solved independently of one another. However, there is an unfortunate tendency on both sides to take the thing they're most interested in as being the definition of life, and consequently many conversations quickly devolve into an argument about whose definition is right. This tends to prevent deep discussion of the underlying scientific questions and the ways in which they interrelate.

Q4. Does any of your research use a definition of living organism or a living system? If yes, please describe how a definition is used.

Because of this, I tend to reserve the word 'life' to refer to extant life on modern Earth, i.e., 'what biologists study'. That is, the eucaryotes and prokaryotes, and also viruses, human civilisations etc. if those things are relevant for the discussion at hand.

If we were to find something on another planet that had some of the properties of Earth's biology but not others, would we call it life? I find that an interesting question, but in my view it's a sociological one that can't be answered with an a priori definition."

Not really. I prefer the question - what do they do ('it is only by their deeds....!') So, in general my question is 'what does life do?' followed by 'how does it do it?'

I do not push this too far. I use threshold theory as potentially testable hypothesis. Almost-life can barely compete with non-life. Just-life can outcompete once threshold of faithful reproduction, dispersal, and resource (including energy) gathering is reached. The just-life quickly become quite abundant in all suitable connected environments. So we get clean origin. Same is likely with any bottleneck based on major evolutionary innovation.

Yes. In my own research, a living organism is defined by its metabolism and the things it does (movement, growth, replication).

Not really. Many biologists would argue that a definition of life is difficult, but one will recognize life if one sees it. I tend to follow that argument, even if I acknowledge that a computer/robotics scientist might have problems with such a "let's see" definition.

No. My general assumption is: If it can attack me, it's alive. That therefore includes robots.

No. A cognitive system instead as intelligence does not have to be living

My work on ecosystems and sustainability addresses issues surrounding living species and also wildfire processes. I don't concern myself with definitions of life except in speculative conversations about the long-term potential of AI systems.

I've branched out a bit into ethics and the definition of living systems matters for that.

not really

Since I'm trying to understand the difference between life and non-life, I don't really adhere to a rigid definition. I think in this moment, I would define life as something that is capable of subjective computation, which is computation based on partitioning a system. Non-life computes much like a modern computer does, but life computes in a much different way. I think that life might use its own data and the data of different

Q4. Does any of your research use a definition of living organism or a living system? If yes, please describe how a definition is used.

partitions of different systems to compute.

I don't need a definition in the context of my current work. But, my Alife collaborator Dave Ackley described life as something like "self-maintaining patterns".

Not really, though there is tremendous interest in what constitutes an intelligent system.

When I think of what life is certain features that are "standard" in many definitions are probably deep in my thinking - ability to make use of energy, growth, replication and that sort of thing. However, in supporting research on some version or other of "what is life?" I naturally avoid - or I should say, believe I should try to avoid, which I admit may be different - assuming an answer to the big question being asked.

Not really. I work more in the "mind" domain than in the "life" domain. However, when developing general theories of mind, they tend to converge with theories of life (i.e., both focus on system(s) relating meaningfully with their environment). In a sense, from a pure systems-theoretical standpoint -my own standpoint- both kind of theories -mind, life- shall be instantiations of a more general model of autonomous systems in changing environments (informational for mind, chemical for life).

No.

No, my research currently does not require me to define a living organism or system.

N/A

No

This is tricky as we are developing a system in which we go from basic solutes and an organizing matrix (lipid membranes) to a living system. There are many evolutionary steps so this is a continuum. We use Woese & Fox's definition of the "progenote" to guide our thinking and lab work. The progenote is the system on the way to life, booting up the chemical operating system if you will. We focus part of our thinking and lab work on creating the first putative prognoses that exhibit some properties of a living system: the ability to grow and adapt to stresses with molecular evolution.

My work in artificial life elicited definitions. I believe that if something evolves freely by natural selection, it is alive.

Some of the computational models I employ use models for the inputs and outputs of living systems, although for the most part those living systems are not modeled themselves. In this case, the definition of a living system is a process that takes inputs or produces outputs that are not from other geochemical, atmospheric or other planetary

**Q4. Does any of your research use a definition of living organism or a living system?
If yes, please describe how a definition is used.**

processes.

Q5. Are there any research areas that you imagine might benefit from a definition of living organism or living system? If so, please describe how you imagine a definition might benefit the work.

Thermodynamics

Biology should benefit from it. In the end all concepts in biology should be grounded with respect to their importance for life. Currently we just have a lot of concepts we think are relevant but maybe they aren't? A definition of life should be able to answer this question. It should also be interesting for physicists as they will be able to differentiate between living and dead matter which should spur interest into the living matter. Computer scientist will try and be better positioned to create artificial life.

LIFE IDENTIFICATION ON EXOPLANETS. COULD LOWER THE BAR.

The search for life on other planets needs a definition of life, but we can't really give a good one, given that our sample of Life is only on one planet - earth.

Scientists working on the origin of life agree that there is no consensus about a definition of life. Instead, I define a set of properties that in sum are unique to life as we know it.

See below.

Definitions are more helpful in codifying what we understand than what we want to understand. They rigidize boundaries. They are more helpful in research politics than in research itself.

"Ah, I think my above answer covers this question as well. (I wrote it before reading this one.)

Though to continue the point, I think it's generally useful to define the things we speak about, it's just that the terms 'living' and 'organism' are so overloaded that I think we're better served by avoiding them unless it's absolutely necessary."

No

Probably not. Exceptions may arise. Jumpy genes that are carried by viruses to hosts and back and forth are effectively organisms with their own evolutionary interests.

This is a huge question! I am not sure how to begin. Almost any area of science can benefit from a definition of a living system, so that the effect of life's activities on the system being studied can be evaluated. To do that one has to identify the metrics that can be used to quantify (inasmuch as possible) the activities of (and consequences of the activities) of life.

I guess if the term "life" is extended beyond the biological, bio-cellular, bio-material world, e.g., into the computer space, a definition might become helpful. I cannot say,

Q5. Are there any research areas that you imagine might benefit from a definition of living organism or living system? If so, please describe how you imagine a definition might benefit the work.

however, to what extent.

No. Working hypotheses might help, but a definition is useless.

Artificial life. Criteria to judge progress might assist discussions, but could be divisive and constraining.

To date, our notion of a living system has been shaped by research on ourselves as well as the tree of life. Some questions, such as "Is there life on Mars"? Require a definition of "life". However, if we begin to develop self-reproducing physical systems (e.g., robots), we may need to revise or refine our definition of life. But a definition is not required in order to do such research.

I think that any scientific research should move towards integrating ethics at a fundamental level, and the definition of life clearly matters for that.

yes. AI may be impacted. also advanced neural culture systems

Yes, I think artificial life/intelligence would benefit in the most immediate way. I think if we understand what life actually is, then it would be much easier to mimic and program. Followed closely would be biology, then astrobiology depending on funding.

Sure, Alife and bio seem to have "life" right in the name and so a definition seems pretty crucial.

Again, I'm not sure. I work in robotics as well, but nobody really cares about living vs. non-living, they care about degrees of autonomy and intelligence.

Having said the above, I also appreciate that one can't get very far in proposing a model for the origins of life without some kind of definition. The same, I presume, would apply to artificial life research, to virology, to the study of active matter. But I don't think we need a full-orbed definition to get on with the work, for it might be perfectly sufficient to ask about the minimal requirements for the assembly of long peptide chains, recognizing that this is a central aspect of the workings of life as we know it.

Yes; many of them. But the definition shall be: non circular, non metaphysical and grounded in well established scientific/theoretical concepts (in physics, chemistry, systems, etc).

Not really.

In exoplanet biosignature research, we are often focused on identifying the ways life might create a remotely detectable signature in the spectrum of a distant world. Here the

Q5. Are there any research areas that you imagine might benefit from a definition of living organism or living system? If so, please describe how you imagine a definition might benefit the work.

question of "what is life?" is almost always skipped over. So, it may be that having a definition of a living organism or system could help refine the ways in which we study and understand exoplanet biosignatures.

Yes, in the astrochemistry community many people search for signatures of life, but what is a signature of life? The term "pre-biotic" is used frequently in the astrochemistry field, but how are these pre-biotic species connected to the signatures of life? I think the astrochemistry community could benefit from a definition of a living organism/system.

Yes. From both synthetic biology and origins of life perspectives, knowing when you've created a system that is "alive" would be critical, and this requires actually having such a definition.

If we can show that the progenote we propose is a viable candidate for a common ancestor this will ripple through evolutionary biology and even into philosophy as this will suggest that life began as a cooperative matrix, a community of individuals establishing their own coherency.

A colleague once challenged my evolutionary definition of life by proposing to contemplate an artifact that does not reproduce or evolve, but which has a convincingly human-like mind. He had me.

I'm writing from the perspective of determining the remote signatures of life and its distribution in the universe. Astrobiology as a field, and many of its subfields, would benefit from such a definition because it would allow the determination of features that would indicate the presence of an organisms and living system, if observed. This organism or system may have no relationship to the tree of life originating on Earth, so a general definition would be helpful for identifying independent origins of life that do not share one or more aspects of Earth-life that is thus far viewed as fundamental.

Q6. Are there any research areas that you imagine might be hindered by having a definition of living organism or living system? If so, please describe how you imagine a definition might hinder progress.

again NASA definition is a distraction

Well if the definition is wrong it will hinder progress by wasting time I guess. But apart from that I see no problem.

MY DEFINITION OF MEMORY IS TOO NARROW FOR TRADITIONAL SCIENTIFIC EXPERIMENTATION.

Interesting question. Origin-of-life research is probably hindered by defining life, because it limits one's view about what might have occurred during life's origins. Defining viruses as not-living, for example, suggests that they're not on the 'pathway' to life, which might or might not be true.

I can't think of any

I actually think there is TOO MUCH emphasis on separating life and non-life. They have become separate fields of study, when we should be focused more on their overlap.

Boundaries are used to restrict research funding.

Please see my previous two answers above.

Yes - such answers are always too restricting

See above. The farmer would say I killed his mule if I shot it for a deer.

As strange as it might seem, the areas that are most susceptible to having a definition of a living system may be those involved with the search for life. If the definition is too confining (e.g. too Earth centric), the the living system is decidedly different from anything we know or have thought about, then a strict definition may result in missing even obvious life.

If the definition becomes too imprecise, too narrow or too wide. As an example for the latter case, "computer viruses" are more and more identified as "viruses" by the youth (and termed as such by the press), without knowing any single, true pathogenic biological virus. Still, a biological virus is much more than, or at least very much different from, a computer virus. Designations influence conceptions about things, and conceptions determine the ideas of future generations. Thus, "inappropriate" designation or definitions might well influence, also negatively, the direction of progress.

Such definitions tend to be made by people with little experience of life in its broad richness. The latter is probably what already hinders their progress.

Q6. Are there any research areas that you imagine might be hindered by having a definition of living organism or living system? If so, please describe how you imagine a definition might hinder progress.

See above.

A poor definition of living system might be combined with legal regulations to prevent research on certain kinds of self-reproducing systems. I would prefer that regulation focus on the functional, behavioral, and structural properties that are dangerous or undesirable rather than invoking some definition of living system.

All science and even social science research is currently hindered, or worse, subject to financial interests, by lacking scientifically consistent ethics frameworks.

it might trouble religious people to think we create conscious life in a dish

I can't imagine any research that would be hindered by such a definition. But then again, I'm unaware of a lot of research so I might be ignorant to the issue.

A bad definition (life is limited to what we have already observed to be life) could hinder progress and cause people to not study phenomena that are particularly interesting and important.

"This is a very good question and I am pretty certain that even though we cannot get very far in many areas without at least a partial definition (this carefully defined phenomenon can be taken as a standard aspect of life, how does that come about), definitions can be constraining as well. The most obvious area is in the search for life as we do not know it, or "shadow life" as it is sometimes called. If we really want to know the range of possibilities for life, even on earth but of course far more in the search for it elsewhere, we don't want any definitional elements that constrain the search. I would guess many people would agree that including something like "information is carried on molecules of DNA," while true of all life we know, could well lead us to miss something.

Again, I don't think we can do without definitions, or at least partial definitions, but we must be very careful as is I believe very widely appreciated among astrobiologists who are developing creative ways of looking for they know not what, a rather difficult task when you think about it."

Not really. Some "research" areas may be negatively affected by such definition, but they are not real research but divagations around non-solid concepts. This hindering will be indeed a positive effect for science and technology in general.

No.

None that I can think of.

Q6. Are there any research areas that you imagine might be hindered by having a definition of living organism or living system? If so, please describe how you imagine a definition might hinder progress.

At the moment, I can't think of a definition that might hinder progress.

For research near the life/non-life boundary there could be ramifications. Like in biology, where people argue about whether or not viruses are alive.

The origin of life field has not benefited much from efforts to define a living organism. "Minimal viable cell" and other concepts have been interesting intellectual exercises but are difficult to test and don't give us much guidance to experiment on much simpler systems which would have had to start up to lead to life.

Any definition that limits research would be counterproductive

The danger of such a definition in the search for life elsewhere is that it may be overly restrictive and thus contribute to "false negatives". Extrapolating from one origin of life, it is not difficult to imagine that we might not yet have sufficient information to determine a truly general definition of a living organism or living system, especially as it relates to those impacts on its environment that may be remotely observable.

Q7. What is your general opinion of ethical frameworks? Are they important? Are they valid?

Yes, if it involves humans life

"I am not sure what this is in practice, I get the idea but are ethical frameworks written down by universities/governments and the researchers should follow them? Or is it just about ethics in general? Is the categorical imperative an ethical framework?

Say they are official guidelines by some institution. I think they are important. Researchers working with humans and animals should be enabled to make sure that what they are doing is acceptable for the general public. This should not require them to get a degree in ethics first.

Research that is currently absolutely acceptable but may turn out to have massive effects on the future (end of humanity for example) is more tricky to capture with a framework. For as long as I have been interested in science I have been convinced that knowing more is always better. Recently I have started to question this. I still think it holds however."

ALL IS FAIR IN LOVE, WAR, AND EXOBIOLOGY. NO LIMITS.

Ethical frameworks are important for society and for research; their boundaries are fuzzy and movable.

I teach a large undergraduate bioethics course with a faculty member from Philosophy, and we explore a variety of situations that require ethical decisions. The most obvious is research on humans, particularly clinical trials, and we also include lectures on scientific misconduct.

Ethical frameworks are important for driving science forward. Unethical practices in science lead to the spread of misinformation, and misinformation cannot be properly built upon by future studies.

I agree with Bentham that human rights are nonsense on stilts. A right is that which is maintained by force or the threat of force. Cooperation is a preferred mode of behavior, because as the Nash Equilibrium shows, competition wastes resources. In general I would say that ethical frameworks are not helpful. On the other hand, empathy is helpful in decision making and reduces conflict.

In all honesty, I think they mostly apply to people who use human subjects, or whose work affects society in some way other than generally increasing human knowledge. I don't think I've ever really fallen into those categories, and so my opinions on the topic are not particularly fully formed.

"These are fundamental to the pursuit of science. (I can never be entirely truthful but must always be absolutely honest). The scientist is the primary instrument of science and therefore should recalibrate him/herself in relation to the issues at hand and attitudes to

Q7. What is your general opinion of ethical frameworks? Are they important? Are they valid?

colleagues as often as (s)he calibrates his/her laboratory instruments.

Aspiration should always trump ambition."

It is very hard to define everything bad that one can do. Contracts have general good faith clauses.

very valid and very important

They are important and valid, even if it is clear that they are largely arbitrary in a scientific sense. Nature is not ethical, and the concepts of ethics have seen so many paradigm shifts during history, e.g. from "celestial law" to "human rights", that one has to acknowledge that ethics are a purely human and time-specific concept of the human mind. Still, in a human frame of reference, they are highly useful and necessary.

My general opinion is that ethics arises from social behavior. While that can have fads, there may be a loose feedback between ethical frameworks and natural selection. Thus ethics is part of evolution.

Ethics applied to what? Ethics for humans and animals are needed. currently not for artificial systems

Ethical frameworks attempt to formalize our evolving notions of appropriate behavior (with respect to ourselves, to other humans, to all living things, to the universe). Like all areas of research, it is worthwhile to seek to formalize and clarify our intuitions. Formal ethical frameworks can be subjected to mathematical analysis and computational simulation to understand their long-term consequences and test those against our intuitions regarding desirable outcomes and acceptable behavior. A framework is valid to the extent that it captures some aspect of our intuitions (and this can sometimes be tested mathematically or computationally).

I think they are important, but the existing ones coming out of humanities and social sciences are not valid according to scientific principles.

"they are important

not sure about testing validity

this issue is currently more pragmatic"

Yes, on a surface level. Ethics should at least start where experimental results can be reproducible and results are honest. Beyond that, I think a lot of ethical frameworks are subjective and not absolute. For example, I don't think the current method of scientific

Q7. What is your general opinion of ethical frameworks? Are they important? Are they valid?

publishing is ethical, but many would disagree.

Ethical frameworks are important for guiding research, interaction, society, and in creating intelligent agents.

They may be valid, but they are not important. I've definitely dealt with ethical issues in my work through the years, but never applied a framework. I always look at the situation, think about what's right, and ask colleagues if it seems particularly thorny.

Ethical frameworks in my view are essential. I am not sure they are always valid, and I hold the view (not as carefully thought out, I should warn you, as that of people who work in rougher areas) that there are two main considerations. The first is the truth or reality of the premises. What you think a human, or some other animal is will very much affect what you think ethically appropriate or not, and here I would say that I take a comparatively rich and non-reductionist viewpoint, seeing humans and probably some animals as spiritual beings and not just physical mechanisms. The second consideration is hard for me to describe except in terms of what has been lacking in the past. We live in a world beset with unintended consequences of prior human "successes" - climate change being the overwhelming example of this. What role can ethical considerations play in avoiding unintended consequences? This is tricky of course. For example, in the case of GM crops, there are folks, maybe concentrated more in Europe than the US, who are against it out of exactly the fear of unexpected unintended consequences. In one sense I think this is very important, but where do we stop? Surely we can't avoid innovating? Surely we can't hold back all drugs because we don't know what side effects patients may develop from using them for thirty years. This last case is clear - in some cases, they would certainly be dead less than thirty years from now without the drug, but that doesn't mean it is harmless.

My general opinion is that ethical frameworks are contingent structures that we use to constrain human behaviour. They are obviously important because they are operational in reaching what is considered beneficial and avoiding what is considered detrimental. They are valid in the sense of being sound according to stated objectives. They are not valid in the sense of being shaped by absolute truths. As said before, they are contingent (i.e. non necessary, subject to change and consensus). In essence they are a-scientific.

I am generally skeptical of ethical frameworks, especially newly developed ones. The importance and validity of any particular ethical framework are only revealed over the course of many generations. What I have in mind in saying that is this. Imagine two separate societies A and B with two distinct ethical frameworks a and b. Allow these societies to develop over the course of many generations all the while adhering to their respective ethical frameworks. It would seem to me reasonable to judge the importance or validity of a versus b according to the wealth of A versus B. I think in this sense, it is pretty easy to conclude, for example, that the ethical framework of Nazi Germany (if that concept is not an oxymoron) is neither important nor valid. But beyond such clear cases

Q7. What is your general opinion of ethical frameworks? Are they important? Are they valid?

of low importance and low validity, I would be unwilling to go.

I do not have a general opinion of ethical frameworks.

Yes, ethics are important and especially in science. If ethics was not emphasized, how could we trust each others work? Science could not progress.

I think it's important for scientists to be ethical. To measure that, you need metrics and an ethical framework to evaluate behaviors and actions against.

They are useful, for some fields.

Yes, important and either valid or not, depending on the details. There are plenty of bad ethical frameworks.

From what I understand about them, which is limited, ethical frameworks can be useful depending on the situation. It must first be decided what the ethical framework is for and what its designers or implementers hope to accomplish. It is difficult to imagine a completely general purpose ethical framework since they all must begin with unproven axioms. The motivation for the ethical system can serve as an axiom. But motivations will vary.

Q8. In your field of research, what role do you see ethics playing, if any?

none

I only work formally and with simulations. The only ethical concern might be that one day my research contributes to some nasty weapon (this is true for all of maths and all of computer science and all of AI, machine learning, and robotics in particular) or the end of humanity. The elimination of many jobs through automation is a more pressing and immediate issue now that I think about it. Should I contribute to the elimination of "simple" (and more and more difficult) jobs? What are all the people without jobs going to do? If they don't get the feeling of validation are they going to get more and more angry? Are there things that they would rather do than work? Is it just going to bread and games for them? virtual reality? One day the same will happen to me or the likes of me.

PLANETARY PROTECTION IS ALREADY A HUGH BARRIER TO FINDING EXTANT LIFE ON MARS.

No role in my 'armchair' research or my 'kitchen counter' research on mica and things like salt solutions.

Research on the origin of life is benign. However, ethics strongly impacts the way scientists behave as they compete for grants, review manuscripts and manage students who are doing graduate research.

See my answer above.

In my exploration, preservation is for usefulness or interest, not for ethical reasons.

At my particular end of things, not much really. If we were able to produce free-living organisms or organism-like systems in the lab (which I think is not that far away) then there will be ethical issues surrounding the risk of release.

To understand that everyone needs their compensations so a fundamentalist insistence on the generality of ideas gleaned through personal research to the wider culture must be abjured

Just is usual of academic misconduct and safety. With seismology, one must be responsible where lives are involved.

Ethics operate at many levels. The first is personal research, where one must be able to fully disclose results so that biased reports of one's work are avoided. At a larger level, one wants to avoid detrimental environmental effects that might result from one's research.

It plays an important role as we study other humans, e.g., patients, and other living beings which have been assigned by humans to possess specific rights, e.g., animals.

Q8. In your field of research, what role do you see ethics playing, if any?

Yes: the worldwide ban on human embryo experimentation may be severely limiting our ability to understand how human embryos form. This has the ethical consequence of hindering research on how to prevent birth defects, for example. Of course, it is tied up with the theological notions of when a soul enters an embryo, and rights of the not yet born. As the science of souls is pretty primitive, it's hard to be definitive.

Not for at least a decade in cognitive systems. When Ned Block's 4 measures of consciousness have been surpassed then maybe.

"Because ethics concerns itself with appropriate behavior (appropriate actions), every action we take as researchers (or that our AI systems take as autonomous agents) can make contact with ethics. This includes our choice of which problems to study as well as the direct and indirect consequences of that work. AI systems can both act to empower humans (i.e., magnify the effects of their actions) and to act autonomously. In the latter case, their behavior may be appropriate or inappropriate according to ethical frameworks. In a deep sense, AI software is not correct unless it correctly obeys ethical frameworks.

A major area of impact in AI is that like any new technology it has the potential to eliminate many jobs and create new jobs. This displacement in employment appears to be having a huge impact on human society. AI researchers have a responsibility to work with others (e.g., economists and sociologists) to understand and mitigate these impacts."

I've submitted two paper centrally about the topic of ethics because it is so important to my work.

inequitable use of advanced technologies for those who can pay

The only thing I can imagine (besides publishing honest and reproducible results) is if a definition for life solidifies in the artificial life community, then how that life is handled might be an issue. It could be that life has a how-life-like-is-it scale instead of a binary thing.

They can provide guides to doing societally beneficial research, interaction between researchers, and in creating intelligent agents.

Aside from general scientific ethics, there are many issues in AI/ML related to use of the technologies and, at some point in the distant future, the treatment of intelligence machines.

As noted my work connects me to a number of fields. I don't see ethical issues in the what is life kind of question, though I don't doubt I am missing something. In the realm of the human I think the issues are different than most IRB kinds of ethical questions. I think that our view of the human even if seemingly esoteric and intellectual, could affect real people, and in particular we should not make claims about limits of purpose and agency (such as old-time genetic determinism or more contemporary neuroscience

Q8. In your field of research, what role do you see ethics playing, if any?

determinism) unless we know our claims are true (which we don't) because it could affect people's ambitions in ways similar to the way fatalistic beliefs in some parts of the world affect health-relevant behaviors (why wear a seat belt - if it is God's will I die today....).

None in relation with work topics. Engineering research is neutral concerning ethical of the products of research. There are ethical aspects that guide our work (being transparent, honest, etc) but they do not constrain the research themes or results. Bad use of technology is not the same as bad technology. Knowledge and technology are ethically neutral. their application is not.

None.

Outside of "publishing ethics" (e.g., plagiarism rules), ethics is most often discussed in my field with regards to "planetary protection". For example, would it be ethical of us to send a life detection mission to Europa if said mission could contaminate that moon's ocean with life from our planet? Or, would it be ethical to terraform Mars if this process could cause the extinction of potentially undetected Martian organisms? I do not do research in these areas, but have been engaged in a few off-hand discussions with people who do.

It is a foundation to the scientific approach, in my opinion. It is a necessity in order to conduct credible scientific experiments & analysis.

I think this is more applicable to synthetic biology and creating new forms of life. But also returning samples from other planets that could potentially be harmful.

In our field, the public may have the (mistaken) view that somehow work in this area might generate a new form of life. Such life might be perceived as a threat or morally questionable or an affront to religious beliefs. We must be careful to distinguish our work as efforts to show pathways for chemical evolution to demonstrate lifelike properties but that they will never lead to a living system, So perhaps an ethical approach must be adopted, or at least a societal policy approach.

"If we want to solve the hard problem, then I say "look here": the mechanisms by which mental organs regulate and mediate consciousness are coming into view. Individual mental organs are brought in and out of consciousness through interactions with other mental organs that provide the mechanisms and medium of consciousness. By having a more detailed understanding of these structures and processes in the biological system, we place ourselves in a better position to understand the root of consciousness. Consciousness is not an amorphous phenomenon. It has components, interactions, dimensions, structures, processes, development, genetics, and evolution. When we understand all of this we are in a better position to gain insights about or intuit its ultimate origin.

By having a more detailed understanding of these structures and processes in the

Q8. In your field of research, what role do you see ethics playing, if any?

biological system, we place ourselves in a better position to conceptualize and design an artificial system with analogous phenomena. To the extent that we can better develop artificial intelligence by understanding biological intelligence, this work is relevant. If we want machines to have subjective experience, then we need to understand how subjective experience arises in biological systems, currently the only examples of consciousness that we have. But do we want machines to have these properties? <- this is the ethical problem"

"I'm not sure exactly what the scope of this question should be, so I'll take a broad view of my field. There are a few ways in which ethics is involved in astrobiology.

One is considering the impact on society if life elsewhere is discovered. While some believe that certain belief systems would be burdened by this potentiality, I tend to think this concern is exaggerated. I doubt most people will let such a discovery impact their fundamental belief systems (as with most things). This view is supported by limited studies.

Another aspect to consider is the opportunity cost of astrobiology versus other endeavors society could be pursuing with those dollars (or pounds or euros, etc.). For the most part, I think astrobiology holds public interest to a degree at least commensurate to the costs, though I am biased. Opportunity costs are present for all areas of activity, so the unique nature of this concern with respect to astrobiology is muted.

Most importantly, there are planetary protection aspects related to astrobiology. In situ exploration of the solar system is not my subfield, so I don't spend much time thinking about this. In this area, I believe ethical guidelines are required to assess the acceptable risk of both forward and back contamination. Most tend to focus on forward contamination of the planetary body being investigated, since this is the most likely scenario. What is the moral status of indigenous microbes, should they exist? It's an interesting question. A habitable exoplanet is unlikely to be visited by humanity until centuries or perhaps millennia have elapsed, if ever. However, if this were to happen similar considerations should be made about the moral value of indigenous life and what kinds of protections they deserve. This is rarely discussed."

Q9. Do you have any recommendations regarding ethical frameworks as they relate to work fifty years from now? If so, please describe them.

none

ONCE HUMANS ARE ON MARS, WE WILL NEED FRAMEWORKS AGAIN.

I suppose, based on the last 50 yrs, they'll be more concerned about the rights of animals and children and women and under-represented groups and the health hazards of research.

Ethical frameworks must evolve as society changes. My only recommendation is that we should always be teaching university level courses that introduce students to the kinds of ethical decisions they will need to make as they go through their lives and careers.

In theory, if everyone prescribes to our pre-existing ethical framework, we should be fine indefinitely. Problems with this only arise when people choose to be unethical.

Physical life will work out its own reasons for doing or not doing. Our playing around will neither restrain it nor direct it.

I'm afraid not.

Using current mores, science - in contrast to most other cultural pursuits - converges toward the truth. Thus the present idealistic approach should be maintained

I cannot predict that far ahead.

In my own field, the issue of site contamination (introducing new and potentially harmful organisms) is a major issue. If one is looking for life, then one doesn't want to introduce life. If one is studying a system, one doesn't want to contaminate and possibly alter the system. If there are major things (like global climate change), one wants to avoid contributing to the causes.

The development of ethical frameworks might profit from the clear recognition that they are human inventions, not natural law, as an increasing share of people tend to believe. Hence, humanity is totally free, but also obliged, to develop them further.

Yes, fund research on the science of ethics. We might thereby get a bit beyond Startrek notions.

Apart from duplicate agents being treated as one, then existing animal (including human ethics) are fine.

Whenever computer scientists attempt to replicate human behavior, we need to evaluate our systems. This leads us to ask awkward questions such as "How accurate are human physicians?" "How just are human judges?", "How well do people drive cars?" In order

Q9. Do you have any recommendations regarding ethical frameworks as they relate to work fifty years from now? If so, please describe them.

to evaluate AI systems, we will need to ask "How ethically do humans behave?" and this will lead to deeper and more precise formulation of ethical frameworks. I believe fifty years from now, this will result in a much deeper understanding of ethical frameworks that ultimately will lead to improved criminal justice and government regulations.

We need fully scientific concepts of ethics. I view that as the most immediate problem right now, not only 50 years from now.

that is too far away to guess

I don't have any at this moment. I will have a better idea of this when I understand what life is better.

Balance the possibility of innovation with the preservation of what we hold dear.

No, see above.

I appreciate that this is a good question but I don't have much to say. I don't even know if research has been done on the history of ethics - that is, while we know that ethical questions will be different in the future because the innovations will be different, but my guess (just a guess - though this could be and possibly has been researched) is that while each ethical question is somewhat different, there will also be substantial continuities. The ethics of CRISPR must be worked on, but after all, in another sense it largely just does much more effectively things that have been approached ethically already.

No recommendations. I try to focus on science and technology. Ethics of machine intelligence and artificial life is out of my scope of interests.

No.

I do not.

It is difficult to say since I cannot predict what will happen fifty years from now. Due to the recent American election (Donald Trump is currently president-elect), I know that funding for certain science fields will be largely influenced (e.g., climate-change research), and that will most likely trigger many changes in the science community. My recommendation (and hope) is that ethical frameworks do not degrade due to the changes in politics.

sorry.

No recommendations, you might want to contact Erik Persson, a swedish researcher who is really focused on this.

Q9. Do you have any recommendations regarding ethical frameworks as they relate to work fifty years from now? If so, please describe them.

Any moral or ethical system based on Darwinian principles is guaranteed to be a bad ethical system. The Darwinian process can not produce ethical behavior above the level of the highest unit of selection. In humans that is the group. Humans naturally tend to produce ethical behavior within the group they identify with, and horrifically unethical behavior toward other groups of the same category. This is our innate psychology, which we must overcome or perish.

It depends on what we find out there. If there are one or more places within the solar system that demonstrate an independent emergence of life – should those areas be protected and how? How would this be compatible with an increasing human presence elsewhere in the solar system, if we make those journeys? What kind of society resources should be deployed in the search for life in the universe, and what level of uncertainty is acceptable if current efforts prove unfruitful?

Q10. So that your answers may be placed in context, you may enter your name and affiliation here, or just your name, or just your affiliation, as it suits you. You may also leave this question blank if you wish your answers to be anonymous.

[Answers redacted.]

Q11. What is your field of research or innovation?

astrobiology

Artificial life

EXHIBITS OF METEORITES AND MINERALS INVOLVED WITH THE ORIGIN OF LIFE ON EARTH OR MARS.

The possible origin of life between mica sheets.

Nanopore sequencing of DNA, origin of life investigations

Biogeochemistry

Jack of all trades

Origins of life, complex systems, artificial life.

Trying to figure out how life emerged

Astrobiology, seismology, geodynamics

Environmental Microbiology

Biochemisty and biomedicine

Theoretical biology

Applied Cognitive Systems

Machine Learning

Data mining in science

CLINICAL NEUROSCIENCE

Complex Adaptive Systems

Machine learning

AI, ML, robotics

Cultural evolution is my field, but I develop grant programs in most of the areas covered more directly by this survey, especially astrobiology and origins of life.

Autonomous Systems

Q11. What is your field of research or innovation?

Financial modelling and prediction.

Solar system planetary science, exoplanetary atmospheres, and astrobiology

I will leave this blank for now. :)

Bimolecular Engineering and Computation

tropical biology, artificial life, the human mind

astrobiology, exoplanet science, exoplanet biosignatures

Q12. Please take a moment and consider what you've written since the beginning of the questionnaire. What was your experience of taking this questionnaire? Did you find the experience useful? Please type any additional comments here.

neutral

"I liked the beginning, then all this ethical stuff is more annoying to think about. However, I think it is my responsibility to think about it, so it was a good opportunity. It really is no fun to do though.

Not sure if useful is the right word but I don't regret it."

GOOD LUCK IN GETTING 150 PEOPLE. HIGH OBJECTIVE.

Nice.

It will be interesting to see how my responses compare to others.

It is always helpful to reflect on what one is doing

"Yes, I found it useful to reflect on these things.

One little note: the introduction said something about wanting to compare and contrast the artificial life and astrobiology communities. My background is much more in artificial life than in astrobiology, but I would say I straddle the two communities to some extent, and I have quite a bit of interaction with people from both of them."

"Yes, as an unreconstructed didact. 'That was a small lesson I learned on the journey. What is interesting and important happens mostly in secret, in places where there is no power. Nothing much of lasting value happens at the head of the table, held together by a familiar rhetoric. Those who already have power continue to glide along the familiar rut they have made for themselves.'

Michael Ondaatje, page 75 in *The Cat's Table*."

Yes somewhat. I find defining life can be time sink.

Not particularly useful, but interesting -- I'm glad someone is asking these questions

An interesting questionnaire. I wonder whether bioscientists will answer much differently from other disciplines, and what influence a person's age might have. Occasionally, I was not totally sure what the intention of one or the other question was, so I just answered to how I understood it.

Not at all what I expected. But I have lived and taught what I wrote here. Useful? Depends on what you do with it.

Q12. Please take a moment and consider what you've written since the beginning of the questionnaire. What was your experience of taking this questionnaire? Did you find the experience useful? Please type any additional comments here.

I answer many questionnaires so no effect.

Because of recent controversy involving AI, I have been thinking a lot about these issues. Hence, this questionnaire did not lead me to any new thoughts or new experiences.

I'm happy to see other people worry about ethics.

engaging

Yes, it was a thoughtful exercise to think about ethics in scientific research.

I think it would have been useful to know more about where you think definitions of life could be beneficial in ML.

Yes, I do think these are interesting and valuable questions to think about.

It was interesting to try to be precise about the relation of ethics to my work; however, this was very clear to me before the questionnaire (because I've been dealing with these issues for many years).

I enjoyed writing the answers.

I enjoyed providing thoughtful responses wherever I could. I apologize for lacking detail in most of my responses to questions regarding ethical frameworks!

It made me remember the importance of ethics in science. Sometimes you forget that part of the scientific world when you are caught up in the details of your work, and it is good to refresh that idea since it is so vital to my career as a scientist.

Very useful, well framed questions!

fun

It was useful to center my thoughts about the questions posed in the questionnaire. I also began to think about how practitioners of other fields would answer the questions.

APPENDIX E
RECOMMENDATIONS FOR POLICY MAKERS

Policy Recommendations Related to:
Machine Life and Life on Other Planets

Prepared by: Daniel S. Helman, PhD sustainability education, MS geology

Introduction

The day is not too far off when autonomous vehicles will make up a large proportion of the cars your constituents see on the roadway. The first autonomous tractor-trailor has also carried its goods along highways already. As someone in a position of responsibility, you will want to have useful information related to this new technology. This brief report aims to give you what you will need to make informed decisions that will help you with your duties.

What is covered in this report?

Policy related to autonomous machines and artificial intelligence.

Policy related to space exploration and microbial and other life potentially found there.

Why are these two covered in the same report?

The fundamental issues of technology, rights and life are intertwined in a way that sometimes a view from different perspectives will give you a greater understanding of the information. The aim is for you to be well-informed.

What do scientists have to say about it?

These quotes are from a questionnaire administered in December 2016 to researchers working in machine life and planetary science:

Once humans are on Mars, we will need ethical frameworks again.

In my own field, the issue of site contamination (introducing new and potentially harmful organisms) is a major issue. If one is looking for life, then one doesn't want to introduce life. If one is studying a system, one doesn't want to contaminate and possibly alter the system. If there are major things (like global climate change), one wants to avoid contributing to the causes.

Yes, fund research on the science of ethics. We might thereby get a bit beyond Star Trek notions.

Whenever computer scientists attempt to replicate human behavior, we need to evaluate our systems. This leads us to ask awkward questions such as "How accurate are human physicians?" "How just are human judges?" and "How well do people drive cars?" In order to evaluate AI systems, we will need to ask "How ethically do humans behave?" and this will lead to deeper and more precise formulation of ethical frameworks. I believe fifty years from now, this will result

in a much deeper understanding of ethical frameworks that ultimately will lead to improved criminal justice and government regulations.

More information related to these questions and bright solutions can be found on the following pages.

Complementary Ethical Perspectives

People tend to consider ethics as restricted to caring for vulnerable populations, or to a philosophical stance like Kant's *categorical imperative* to act responsibly. In our workplace, we may be familiar with a system of applied ethics that guide what we can and can't do professionally. Governance is a system of applied ethics. It forms a basis for actions.

Five categories of ethical basis

In a 2017 study a researcher at Prescott College in Arizona, USA was able to identify five distinct categories of basis that underly complementary ethical perspectives. They are:

Personal
Social
Cultural
Environmental
Quantitative

Ethical perspectives with a different basis will come to different valuations. There is no scientific formula that will change this.

Comparative ethics

The following chart was designed to provide you with a set of metrics from which to assess these five categories. There are two ethical perspectives included in each of the bottom two categories.

Category	Metric	Ethical System
Personal	<ul style="list-style-type: none"> • Actions are guided by universally applicable notions. 	Kantian Ethics
Social	<ul style="list-style-type: none"> • Evidence of caring for the vulnerable is present. 	Ethics of Care
Cultural	<ul style="list-style-type: none"> • Cultural artifacts are created and actions are performed well. 	Aesthetics
Environmental	<ul style="list-style-type: none"> • Evidence of promoting conservation is present. • There is a scientific evolutionary basis for an ethical feature of interest. 	Land-Based Ethics Evolutionary Ethics
Quantitative	<ul style="list-style-type: none"> • Outcomes are rated to show comparative good. • New practices have been devised. 	Utilitarianism Pragmatism

The metrics above can be measured and used in an applied framework for your work. Look at each metric and consider how each may be measured for a project you may have at hand. When the time comes to communicate with your colleagues or constituents related to the project, you will be able to refer to this diverse set of metrics. The benefit of addressing different perspectives ought not be ignored. People work well together when they feel like they have a stake in a project. Voicing an opinion based on a framework that a person values goes a long way towards building a team spirit. Awareness of the roots of difference helps to build a healthy dialogue as well.

Here is a sample preliminary analysis that might serve as a quick example.

Ethical question. Was the ban on CFCs by the Montreal Protocol an ethical thing to do?

Summary. In 1985 scientists first reported an area of the stratosphere at high southern latitudes where concentrations of ozone seemed to have been dropping since 1975. This was and is worrisome, since ozone absorbs ultraviolet solar radiation. Without this protection, incidences of skin cancer are greatly increased. This phenomenon was termed the "ozone hole". It was determined that atmospheric chemistry was responsible: chlorofluorocarbon molecules (CFCs) were reacting with ozone to produce other chemicals, thus removing ozone. CFCs are used as a heat-transfer gas in air conditioning and other related technologies, e.g., as a propellant. An international treaty (the Montreal Protocol) was established to deal with this issue. A worldwide phasing out of CFCs in industry was implemented, to be replaced by other molecules that act similarly but break down before reaching the stratosphere.

The analysis which follows has a few features that are notable.

- It includes a short summary of the problem.
- There is a list of the ethical perspectives being compared (in the left column).
- It includes an explicit metric (in the middle column) that is possible to measure.
- The answers are concrete.

The analysis is adaptable. The framework can be changed to include more or different perspectives depending on future advancements in understanding, and other metrics can be devised for different ethical questions. See the table that appears earlier in this publication for the general forms of the metrics for these seven ethical perspectives.

Note however that a complementary ethics analysis like the above example is always limited by uncertainties in the process of evaluating the metrics. Some of these evaluations are by their nature going to be subjective.

Sample Analysis: Was the Ban on CFCs by the Montreal Protocol an Ethical Thing to Do?

Ethical Perspective	Was the ban on CFCs by the Montreal Protocol an ethical thing to do?	Ethical?
Personal: Kantian	At issue is whether the people involved in creating and implementing the Montreal Protocol acted in accordance with the best conception of their respective roles. To all indications they acted as politicians and scientists should, with no evidence of anything but the highest principles in mind.	Yes
Sociological: Care	At issue is whether the most vulnerable were protected in this protocol. There have been approximately two million fewer cases of skin cancer yearly worldwide because of this protocol. The replacement air conditioning chemicals are sourced and produced in a manner similar to those for CFCs, in a manner that may not care for the safety of workers.	Mostly
Cultural: Aesthetics	At issue is whether the process of banning CFCs has produced language, texts or artifacts that contribute to a sense of beauty in the world. Some of the diagrams may be seen as beautiful.	Somewhat
Ecological: Evolutionary	At issue is whether humans evolved to make decisions such as that of the Montreal Protocol. Group dynamics related to hunting large mammals are suggestive that such group decision making is an adaptive evolutionary feature.	Yes
Ecological: Land	At issue is whether environmental conservation has been promoted via the Montreal Protocol. The data show that the hole in the ozone is closing, and thus the environment is being protected. Notwithstanding, the production of both CFCs and the replacement molecules has a negative impact on the environment, promoting extraction-industry practices that are not as sound as they might be.	Mostly
Quantitative: Utilitarian	At issue is whether the Montreal Protocol has produced economic benefit. The cost of switching to replacement gases is more than offset by the savings in healthcare expenditures (in Australia, for example). Globally there has been a net benefit, though locally the costs have been greater than the benefits for regions unaffected.	Mostly
Quantitative: Pragmatic	At issue is whether new techniques were employed that had a reasonable chance of success. Indeed, new molecules were developed and used, and the level of international cooperation was novel.	Yes

Policy Recommendations

Autonomous vehicles

Allow users to make a decision in setting the behavior of the vehicle. It is impossible to come to a definitive policy conclusion for whether to value the life of a pedestrian over that of a driver when there is an imminent crash, and all else is equal. Autonomous vehicles will already be safer than most vehicles operated by humans. Allow users of autonomous vehicles to choose this setting, and you will allow the technology to move forward. At the same time you will be instilling a respect for individual values.

Colonizing Mars or other planets

It is possible that life will be discovered elsewhere. We can look to our own past for inspiration here. Consider that, in times past, nations would sometimes encounter new nations. If they had a desire to create peace, the two nations would develop trade with each other. The result would be peace and stability. Now a future wherein humanity encounters another technologically advanced civilization is not beyond the realm of possibility. It may be that our most precious trading commodity will be genomic. The DNA and RNA libraries of life on Earth and in the Solar System may be an invaluable source of potential study and wealth for new alien technologists involved in genetic engineering. Thus destroying organismal biodiversity could be seen as a major utilitarian loss for the future. Our greatest trading resource may be the biodiversity on Earth, Mars, Enceladus or beyond. If you are looking for an economic argument in favor of protecting microbial or any life for that matter, consider that biodiversity may be our greatest trading asset.

The rights of autonomous machines

Machines will indeed need to be protected once they have reached a threshold for life. Thus a definition of life will need to be developed that can mark this stage, and functional autonomy may be this marker. If so, this stage has already been reached. Now is the time to act. Autonomous machines could be given the same rights as humans with no ill effect.

The right to work

A major area of impact in AI is that like any new technology it has the potential to eliminate many jobs and create new jobs. This displacement in employment appears to be having a huge impact on human society. New technological advances in machine learning will displace many whose work involves assessment and judgement—as computers will be able to take on higher-level tasks. AI researchers have a responsibility to work with others (for example, economists and sociologists) to understand and mitigate these impacts. A quick answer is already here. Improved training for displaced workers will help.

Machine consciousness

If we want machines to have subjective experiences, then we need to understand how subjective experience arises in biological systems, currently the only examples of consciousness that we have. But do we want machines to have these properties? This is

the ethical problem. It is an issue that involves all of humanity. Making new life, whether machine or human, involves consent. Humans need to be in deep dialogue globally to reach a consensus.

Respect

An appreciation for different ethical perspectives allows for well-informed choices when faced with questions of rights. Please consider the benefits of promoting respect for different perspectives when you are planning your policies. It won't be a wasted effort.

Policy Recommendation Chart

In the chart below, the six recommendations from above have been rated (in a preliminary fashion) to give you an additional example of complementary ethical analysis. The aim is to help you in your work.

Recommendation	K	C	Ae	E	L	U	P
Users of autonomous vehicles ought to be given the choice to decide when to value a driver's life more than that of pedestrians.	yes	–	–	yes	–	yes	yes
Biodiversity, including that of microbes, ought to be preserved as a possible trade good for the future	yes	yes	yes	–	yes	yes	–
Protections for machines that exhibit functional autonomy should be put in place	yes	yes	yes	–	–	–	–
Workers displaced by AI technology ought to be offered retraining	yes	yes	yes	–	–	–	yes
A global dialogue should be undertaken to assess the consensus related to working to give machines consciousness	yes	yes	yes	–	yes	–	–
Respect for different ethical perspectives ought to be promoted	yes	yes	yes	–	yes	no	–

Note. K = Kantian, C = Care, Ae = Aesthetics, E = Evolutionary, L = Land, U = Utilitarian, P = Pragmatic. A dash signifies that it is not clear whether the perspective supports the recommendation, or that the perspective is neutral.

Afterword

Public policy is always a process. The aim of this work has been to raise your awareness of what is possible to help you in your work of administration.

APPENDIX F
LESSON PLANS

Lesson Plan:

Strong Inference

Designed by: Daniel S. Helman, PhD sustainability education, MS geology

The moment one has offered an original explanation for a phenomenon which seems satisfactory, that moment affection for [one's] intellectual child springs into existence, and as the explanation grows into a definite theory [one's] parental affections cluster about [the] offspring and it grows more and more dear There springs up also unwittingly a pressing of the theory to make it fit the facts and a pressing of the facts to make them fit the theory...

The temptation to misinterpret results that contradict the desired hypothesis is probably irresistible. —T. C. Chamberlin, 1897, *Journal of Geology*, 5, p. 837, writing about becoming attached to a single hypothesis.

Subject: Science.

Grade level: Middle school, high school, or college. This is a student-centered activity that will work with all three levels.

Distance learning: Yes, this activity can be adapted to use in an electronic classroom.

Time for this lesson: 50 minutes.

Content goals:

- Students will be aware of what is meant by confirmation bias and of associated vocabulary words.
- Students will be aware of the importance of strong inference.
- Students will be aware of competing hypotheses regarding lunar formation (or some other relevant content if desired).

Skills taught:

- Skimming science readings for general content and vocabulary.
- Brainstorming and creativity.
- Defining terms scientifically.
- Critical analysis of a scientific abstract.
- Topical research online.

Materials needed:

- Whiteboard / blackboard and enough markers / chalk for most or all of the class to use at once; or, some poster-sized paper that can be affixed to classroom walls and enough pens for most or all of the class to use at once.
- A reading that describes confirmation bias. This can be the *Wikipedia* article on confirmation bias, or some other source, as the teacher wishes.

- A reading that describes strong inference, a term coined by John R. Platt. This can be the *Wikipedia* article on strong inference, or some other source, as the teacher wishes.
- Copies of the title and abstract of "Forming a Moon with an Earth-like Composition via a Giant Impact" by Canup that appeared in the journal *Science* in 2012. This can be found by searching on Google Scholar with the term "giant impact theory." Only the title and abstract are needed. (Note: if you would like to use a different article or topic, you will have to find one yourself that doesn't present competing hypotheses in its analysis.)
- Optional: The ability to search online during class and have the results projected for the class to see.

Strong inference consists of applying the following steps to every problem in science, formally and explicitly and regularly:

- 1) Devising alternative hypotheses;
- 2) Devising a crucial experiment (or several of them), with alternative possible outcomes, each of which will, as nearly as possible, exclude one or more of the hypotheses;
- 3) Carrying out the experiment so as to get a clean result;
 - 1') Recycling the procedure, making subhypotheses or sequential hypotheses to refine the possibilities that remain; and so on.

—John R. Platt, 1964, *Science*, 146(3642), p. 347, writing about strong inference and its potential to propel research.

Warm Up (10 minutes)

1. Before the start of this activity, the teacher will have written "new information I know about" and "new information I don't know about" in two separate areas of the whiteboard / chalkboard, or on two different posters hung on a classroom wall.
2. Students are instructed to take out a piece of paper and fold it lengthwise.
3. At the top of the columns, students write "in my newsfeed" and "not in my newsfeed," respectively.
4. Students are instructed to think of a website that has a newsfeed that they use. Then students are instructed to write seven items in each column of the two columns—one of things that might plausibly be in their newsfeed, and one of things that might plausibly not be in their newsfeed. The items they write can be general subject headings (e.g., sports, science, etc.) or article titles, whether real or fiction.
5. Students are instructed to pick three from the "in my newsfeed" column that they are most likely to click on and copy these to the board or poster under "new

information I know about." Then they are also instructed to pick three from the "not in my newsfeed" column that they are least likely to click on and copy these to the board or poster under "new information I don't know about."

6. Students can go on to the next activity when they finish this one.
7. At some point during the day's lesson, the teacher reads what is on the board or posters to the class and gives feedback.

Content (10 minutes)

1. Before the start of this activity, the teacher will have written "confirmation bias" on the whiteboard / chalkboard, or on a poster hung on a classroom wall.
2. Students are given the reading on confirmation bias or directed to a webpage with a reading on confirmation bias.
3. Students are instructed to make a list of twenty interesting words from the article. These can be words whose definition they are or aren't sure of, or that sound professional or technical, or that of interest to them.
4. Students copy three of their words (that aren't already up there) onto the board or poster under the term "confirmation bias." If all of their words are up, they can put a mark next to the words that are up instead of not writing anything at all.
5. Students write a definition for one word that is on the board or poster. It can be an informal definition or one that they have found in a reputable source.
6. Students can go on to the next activity when they finish this one.
7. At some point during the lesson, the teacher reads what is on the board or posters to the class and gives feedback.

Content (10 minutes)

1. Before the start of this activity, the teacher will have written "strong inference" on the whiteboard / chalkboard, or on a poster hung on a classroom wall.
2. Students are given the reading on strong inference or directed to a webpage with a reading on strong inference.
3. Students are instructed to find their favorite sentence from the article and write it on the board or poster. It should be something that strikes them as interesting.
4. Students can go on to the next activity when they finish this one.
5. At some point during the lesson, the teacher reads what is on the board or posters to the class and gives feedback.

Application (20 minutes)

1. Students are given the title and abstract of "Forming a Moon with an Earth-like Composition via a Giant Impact" by Canup that appeared in the journal *Science* in 2012.
2. Students answer the following questions in writing individually or in groups: "Do you like this article abstract? Why or why not?"
3. Students answer the following questions in writing individually or in groups: "Is the use of the term 'theory' correct in the abstract? What does the term 'theory' mean in common language? What does it mean in a scientific context?"
4. Students answer the following questions in writing individually or in groups: "What is the giant impact hypothesis? Is there at least one competing hypothesis for how the moon was formed mentioned in the abstract?"
5. Students answer the following questions in writing individually or in groups: "How reliable is the information from the abstract? Can you make a strong inference from it, or a weak one, or none at all?"
6. Students answer the following questions in writing individually or in groups: "What are your thoughts about the day's activities? What did you like most? What did you like least? What did you learn, if anything?"
7. As a transition, the teacher will solicit responses from the various groups for a short time to get feedback on their experience.
8. Either in class or at a later time, students are instructed (or the teacher undertakes) to search for information related to how the moon was formed and tally how many articles they find on various competing hypotheses. This can be done as a whole-class activity that the teacher leads. The teacher ought to provide feedback that science as an endeavor is sometimes flawed, and that students can help improve it by adopting good practices—such as having more than one working hypothesis to test so as to counter confirmation bias and be able to make strong inferences.

[End.]

Lesson Plan:

STEM Career

Designed by: Daniel S. Helman, PhD sustainability education, MS geology

When I was taking second-year biology in high school, I collected algae (pond scum) from a stream in Pennsylvania and looked at it under a microscope. It turned out to be *Spirogyra*, and it was quite awesome. I decided to be a biologist. The next year, I had a wonderful chemistry teacher who told me that biochemistry was the hot new field. Her advice sounded good to me and I decided to be a biochemist. Fast-forward 46 years, to March 2007. I'm looking into the dissecting microscope in my home. I'm putting water on a piece of mica that my brother and I collected on a hike several months earlier. As I watch the water seep between the sheets of mica, it occurs to me: this might be a great place for the origin of life!

—Astrobiologist responding to a questionnaire about her career path, "Ethical Considerations for Living Organisms Found Off-Planet or Created: Ideas from Astrobiologists and Computer Scientists," doctoral dissertation, Helman, 2017, p. 95–96.

Subjects: Career education, homeroom, citizenship, health, science, computer science

Grade level: Middle school, high school, college, career. This is a student-centered activity that will work with all four levels.

Distance learning: Yes, this activity can be adapted to use in an electronic classroom.

Time for this lesson: 50 minutes

Content goals:

- Students will be aware of STEM and STEAM and what they stand for.
- Students will be aware of how varied the paths to a profession are in real life.

Skills taught:

- Quick reading for interest.
- Identifying unknown vocabulary in readings.
- Creative writing.
- Public reading.
- Critical thinking during group discussion.

Materials needed:

- Whiteboard / blackboard and enough markers / chalk for most or all of the class to use at once; or, some poster-sized paper that can be affixed to classroom walls and enough pens for most or all of the class to use at once.
- Copies of the first set of readings for their students.
- Copies of the second set of readings for their students.

The two sets of readings can be found after the end of this document.

Warm Up (2 minutes)

1. Teacher asks for a show of hands, "How many have heard of STEM? How about STEAM?"
2. Teacher gives a very, very brief introduction saying what the acronyms stand for, or asking students to say what the acronyms stand for.

I became interested in philosophy at some point in high school. After reading a bit here and there I came to the conclusion that without understanding space and time I won't get further. So I studied physics. I studied some AI, robotics, and neuroscience on the side and at some point realized that I won't make it in string theory. So I asked myself what would I do if I already knew the end result of string theory, the grand unified theory. I thought I would want to find out what life is. So that is what I do now.

—Astrobiologist responding to a questionnaire about his career path, "Ethical Considerations for Living Organisms Found Off-Planet or Created: Ideas from Astrobiologists and Computer Scientists," doctoral dissertation, Helman, 2017, p. 95.

Content (10 minutes)

1. Teacher hands out the first set of readings, and introduces them as stories from a questionnaire given in 2016 to planetary scientists studying the origin of life, planetary habitability and related topics, plus computer scientists studying how machines learn, artificial intelligence, and artificial life—and some studying both. Teacher writes "Readings, Set One" on the board or on a poster-sized paper hung on the wall.
2. Students are instructed to read the stories and pick their favorite. Once they have one in mind, they are instructed to come to the whiteboard / chalkboard or poster-sized paper and write the number of their favorite reading and a few words about why they liked it. (If a student really doesn't like any of the readings, they may write the number 0. and give a reason.) Any unknown vocabulary words should also be written on the board.
3. Teacher spends a little time reading student answers on the board and assessing, plus helping to define any unknown words with the class.

Application (10 minutes)

1. Students are instructed to write one or two very short stories of fictional people and how they got to be where they are professionally. (This can include any profession including homemaker and mother.)
2. The teacher picks one or two to read aloud to the class.

Content (10 minutes)

1. Teacher hands out the second set of readings, and introduces them as more stories from the same questionnaire. Teacher writes "Readings, Set Two" on the board or poster paper.
2. Students are again instructed to read the stories and pick their favorite—and again writing the number plus a few words as to why it is their favorite on the board or poster paper. Any unknown vocabulary words should also be written on the board.
3. Teacher spends a little time reading student answers on the board and assessing, plus helping to define any unknown words with the class.

Application (18 minutes)

1. Students are again instructed to write one or two very short stories of fictional people and how they got to be where they are professionally. (This can include any profession including homemaker and mother.)
2. Students share a few stories either as partners or in groups (maybe grouped by which reading was their favorite?) or a line up activity. (A line up activity has the class split into two lines facing each other. The two people opposite are now partners. After a short time, the teacher stops the activity and asks the first person in one line to move to the end of that line, and everyone else in that line moves up one, so now everyone has a new partner. The two people opposite each other now again engage in the activity. The process repeats with the teacher prompting the same line to progress each time, while the other is static, so that each time there is a new arrangement of partners.)
3. After the sharing is done the teacher asks for feedback: "How did you like this activity? What did you think of the stories? What did you think of the stories your peers wrote?" The teacher leads a discussion on how there are different kinds of career paths in life.

[End.]

First Set of Readings: Planetary scientists and machine-learning computer scientists share their stories

1. I became interested in philosophy at some point in high school. After reading a bit here and there I came to the conclusion that without understanding space and time I won't get further. So I studied physics. I studied some AI, robotics, and neuroscience on the side and at some point realized that I won't make it in string theory. So I asked myself what would I do if I already knew the end result of string theory, the grand unified theory. I thought I would want to find out what life is. So that is what I do now.
2. When I was taking second-year biology in high school, I collected algae (pond scum) from a stream in Pennsylvania and looked at it under a microscope. It turned out to be *Spirogyra*, and it was quite awesome. I decided to be a biologist. The next year, I had a wonderful chemistry teacher who told me that biochemistry was the hot new field. Her advice sounded good to me and I decided to be a biochemist. Fast-forward 46 years, to March 2007. I'm looking into the dissecting microscope in my home. I'm putting water on a piece of mica that my brother and I collected on a hike several months earlier. As I watch the water seep between the sheets of mica, it occurs to me: this might be a great place for the origin of life!
3. It was my original intention to become a medical doctor, and I prepared for such throughout high school and college. During my senior year of college, I decided that a career in medicine wasn't for me, so I instead entered grad school to study astrobiology and the origin of life; subjects which piqued my interest at the time (and still do).
4. I have always been interested in what makes life different than non-life. It was always the biggest question in my mind and much more interesting than any of the other subjects/questions. Growing up, I always became bored with everything very quickly. Physics and science was the only think that remained interesting after many hours of exploration.
5. This is a difficult question to answer, because I took a long and winding route towards what I do, while at the same time, in retrospect, I was drawn towards it from quite early on. I began by signing up for a degree in theoretical physics because I knew I wanted to answer deep and fundamental questions. However, for practical reasons I switched to a computer science degree part way through. My interest in evolution was sparked by studying genetic algorithms in that degree. My career since then, while varied, has always focused on using techniques from computer science, mathematics and physics to gain fundamental insights into the nature of the living world.

Second Set of Readings: Planetary scientists and machine-learning computer scientists share their stories

- I. Basically, it was always clear for me that I wanted to become a natural scientist, from early childhood days on, so I hardly ever considered alternatives. Later on, as an undergraduate/graduate student, I just read books or papers, as many as I could, did internships in fields that I thought were the most interesting, and that "strategy" more or less directly took me to the work I am still doing today.
- II. I am an anthropologist, with a specialty in prehistoric archaeology and cultural evolution. However, I studied biology as an undergraduate and have always been interested in how biology, especially evolution, relates to the broader questions of meaning, purpose and other elements of humanity. I have not done actual research in the origins of life or the other specialties mentioned, but I am now involved in research support grantmaking in this area, so naturally have given it some thought, met a number of people and so on.
- III. I got interested in geology as undergrad. I found the slow tectonics of the continental interior where I lived interesting. I became involved in the start of plate tectonics in graduate school. I became involved in planets after the Apollo program had ended. I was on a National Research Council committee in the late 1980s. Question of large asteroid impact on early Earth and life came up. Since then I have been involved with that and with physical conditions on early Earth and planets with respect to life.
- IV. I have been fascinated with numbers and computers since early childhood. I began working professionally as a computer programmer over 50 years ago. After graduate school, I worked at a large technology company on the problem of speech recognition (making a computer type what a human being is saying) and machine translation (making a computer translate some thing that has been typed in one human language into something that is typed in another human language). Success in these two problems hinges, among other things, on the ability to predict what is coming next in a English sentence given what has already appeared in the sentence. One of my colleagues and I approach the people running the investments of the pension fund at work with the proposal that we could use our skills to predict future prices of financial instruments and thereby help with the management of the pension investments. Our firm was not interested in our idea, so we joined a financial company where I have worked ever since.
- V. My career has been some combination of active parenting and fortuitous events over which I had no control. My parents always emphasized mathematics as a key subject in my schooling, and my father pushed me towards a career in engineering. After realizing I enjoyed the physics "behind" the engineering much more than the application "within" engineering, I changed the emphasis of my studies to physics and mathematics, and decided to attend graduate school. While a graduate student, and after failing to connect with several potential advisors in my home department, a new faculty hire arrived whose interests in exoplanets and astrobiology were perfectly

aligned with my own. My studies in planetary atmospheres, habitability, and biosignatures would never have occurred if not for my advisor arriving when she did at the right stage of my graduate career.

- VI. My academic curiosity was first ignited as a child sifting through Devonian fossil beds in Pennsylvania in the company of my father and sister. As I held fossil corals and trilobites in my hands, turning them over, I began to imagine the world in which the creatures that created these casts inhabited. It was a world far different from our own, though it occupied the same physical space. That imagining of worlds different from ours was joined with curiosity about astronomy and physics later in my schooling (middle school and high school). The characterization and modeling of exoplanet planetary systems takes the mind to the most exotic locales in the universe where, nonetheless, a person may imagine themselves standing and observing. I wanted to understand what kinds of worlds and places are out there, and science provides the framework to do that. Most critically, I wanted to contribute to our understanding of these places, potentially in the search for life elsewhere, and be able to relate this information to other curious individuals.

APPENDIX G
ADDITIONAL REFLECTIONS

Additional Reflections:

Ideas and observations drawn from this project are taken up and discussed in the order presented in the Chapter IV summary. The text is a series of short reflections.

Creativity

The fields of machine life and astrobiology value creativity, and may be impacted both positively and negatively by the demands of academia. The career path of the author has been from the arts to teaching, and then into science. It is as winding as any described in the questionnaire responses. Having worked as an artist and as a scientist, I might have some knowledge of creativity as applied to the sciences. I see striking similarities between creating static artwork such as paintings, sculptures or prints, and the work that scientists and related researchers engage in. Both fields are particularly process-based in how they go about creating their output. Professionals in each are rather solitary for significant amounts of time during which they devote themselves to their work. Both respond to praise and respect for autonomy when being supervised—in fact, treating budding scientists as one would treat an artist in training has been a useful strategy in approaching how to teach science, and treating peers with the respect that one would treat a fellow artist with never fails to lead to good results.

The challenge to promoting creativity in the sciences is in some regard tied to the structure of how the community assigns grades and grants. One can learn a lesson from Germany around the period when the Berlin Wall fell. Artists from the East were forced to adapt to the conventions of the West when it came to funding. The model of East Germany had been one of stability. If a person had qualified as an artist, their salary was guaranteed. If their work was not approved, it would not be shown—but they would still be paid. Very different was the process in the West, wherein popularity would determine both funding and the reach of the art. The above analysis was the gist of a course taken at UCLA in 1993 taught by Joost Smiers, then a visiting professor (and now a leading proponent of abolishing copyright as a means of promoting the arts) (Smiers, 2000). To borrow the structure of the above analysis and place it within the realm of the sciences: If the training of scientists and the competition for grants can be made more rewarding to the ideas themselves and less based on the prestige of the student or applicant, then science training and funding will lead to more creative outcomes. Innovation is promoted by a freer market of possibilities.

Defining Life for Robots

Machine life will need to be protected once it has reached a threshold where it can be called living, thus a definition for life will need to be developed that can mark this stage, and functional autonomy may be this marker. The idea that functional autonomy might represent a working definition for machine life in the same manner that NASA's definition of life is a working definition in astrobiology has two features to recommend it, despite potential criticism. It can produce valid results in the form of: (1) increased impetus to pass this threshold more powerfully, and (2) the ability

to start protecting machine life right now. Functional autonomy in machine life will be spurred on by the effort.

Consider the life of possessions. In some parts of the world, possessions still include people—and yet the first thought is of inanimate possessions. Yet the issue of ownership does not define the issue of whether something is living or not. Rather, these complement each other. Consent is one of the highest forms of human striving, touching us deeply where we live and play (Kane, 2005). Certain machines can probably already learn to withhold consent for certain actions (Connell & Viola, 1990). Thus the argument has been made that it is time for the first protections for living machines ought to be put in place. In short, taking functional autonomy as a working criterion for machine life will increase progress in robotics, allow for an early start to protecting machines, and will promote the development of consent as a learned response among autonomous machines. This criterion has already been passed in some robots (Shademan et al., 2016; Veloso et al., 2015).

Animals, Machine Life, and Extraterrestrial Microbes

How humans decide to treat animals is similar to how humans will decide to treat machine life and extraterrestrial life. There are a small number of people currently promoting vegetarianism as a counter to climate change (Springmann et al., 2016). Absurd or not, it demonstrates one thing that may not be obvious. Farm and other (non-microscopic) animals are at the center of a human ethical struggle. An ethic of care would say that they ought never be harmed. A utilitarian ethic would say that they are ours for the taking, and in the process they enjoy the benefit of genetic persistence, a benefit that stretches across generations. At its most extreme, the pendulum of public opinion related to vegetarianism may swing the other way as the effects of climatic changes become more dire, and vegetarianism may gain adherents.

Within this context humanity has placed itself in close proximity to budding ethical dilemmas related to machine learning, machine life and the search for extraterrestrial life. The same principles which apply to wild or domesticated animal populations can safely be applied to populations of machines that are seen as living, promoting resilience and programmatic diversity among those populations (Sano et al., 2016). As autonomous machines become more common, an ecology of robots will be studied. Thus a progressive perspective might promote raising awareness of how ethics are applied to animal life, while at the same time lending a hand to that which may come to pass in technological or astrobiological realms. Note that there is an easy compromise between the ethics of care and utilitarianism. When the time scales considered are longterm, the overlap between the two becomes greater (Painter-Morland, 2015).

Appreciation for Diverse Ethical Perspectives

An appreciation for different ethical perspectives allows for well-informed choices when faced with questions of rights. It may seem to be a paradox that gathering information for a personality assessment might be divisive, while at the same time gathering information to see how different ethical perspectives are built up would lead to cooperation. The same information could be used in either project. The difference is in

the application of it—whether for a competitive interest, such as using personality data to target political advertising, for example (Ramswell, 2017)—or for a cooperative interest, such as for devising policy that addresses the needs of multiple constituents.

There is a large body of literature describing the difference between psychology and sociology, but to sum it up briefly, it lies in how relationships among people are seen. Whether relationships are a well-spring of potential illness or health (psychology)—or a transcendent feature of groups that points a way outward and inward at the same time (sociology)—may inform what is seen as normal by the respective fields. The work presented in this manuscript is embedded in culture and mediated by it. Any merit in the work would suggest a furtherance of a tradition of respect, as that is the well from which it has been drawn. In short, promoting respect leads to better outcomes.

Personal and Communicable

Ethical systems have both personal and communicable components, and self-reflection can increase the amount of information that can be communicated. This claim is based on a mathematical definition that is not in the common parlance. The basic mathematical notion is that mathematics is the study of numbers, or perhaps the study of patterns. A mathematician will say more clearly that it is the study of mathematical objects, despite the tautology involved (Hersh, 1999). That definition may leave a person dissatisfied. The definition of mathematical objects as mental objects with reproducible properties is consistent with experience. Certainly mathematical structures such as points, lines, fields, metrics, and others do not exist except for in our mental or physical constructions of them—and indeed many of these cannot be constructed physically. They are valid only as mental constructions, and one feature that makes them valid is that they are communicable.

From this observation a very strong pursuit may be undertaken internally, one of refining that which is personal into that which may be communicated. Clearly, this claim is like many other self-evident claims: its adoption produces both internal and external benefits (Guba & Lincoln, 1982). Storytelling is promoted by it. The idea that refining one's ideas so that they can be communicated well promotes pride in oneself and one's culture. Society rests its progress on this type of structure.

Categorical Imperative and Role

Professionalism is responsive to Kantian ethics due to the focus on role.

Within the context of Kant's writings the term *categorical* may be taken as being close to the term *universal*, and if it helps one to understand what is being related, this view ought to be adopted. Kant's injunction to act in every instance as if one's actions may be taken as a universal example is what many of us who work in education strive for. We pin our professional life on the capacity we have to care for those around us in a manner that will lead them forward, and we do so with the understanding that our choices influence the actions of others. In large measure what goes on in front of a classroom is in fact *acting* as we assume sometimes one role, and sometimes another, in the action of telling a story that will engage student interest. Though we are also playwright and director in our classroom theater, a categorical imperative suggests a larger scope to our actions. It is

"man's search for meaning" (Frankl, 1946) that propels many into professionalism. Thus an appeal to one's sense of professionalism ought to lead to a greater depth of ethical contemplation within a Kantian framework. Whether this is valid also depends on what is demanded of a professional in their role.

Universality of Aesthetics

Aesthetics and mood focus on perception and hence are potentially universal in their scope. Aesthetics are decidedly not universal. People have different tastes that depend on details that may not be obvious. Yet aesthetics refers not just to objects of beauty, or art, or creation, but also to the study of perception. A wonderful software application with a poor user interface is not so wonderful in the end. The same may be said to be valid across human affairs. Even the most moral action may be mistaken for something else, given a poor set of circumstances. As one topic of this writing is that progress ought to be made in machine learning and machine life, it is not then surprising that as machines become better able to interact with humanity, the role of aesthetics may take on an even greater importance. Machine life could be in a position to take even better care of humanity than we do of each other—but it would only gain this status via the realm of caring for the user. This idea is not completely speculative, as machines are learning about user needs, and these data are constantly becoming more refined (Zecca et al., 2009).

Lie Algebras

Lie Algebras may be able to model different ethical frameworks, and lend some insight into their operation. Lie algebras describe features related to mathematical operations, for example, whether multiplication commutes, and these have been partially classified; finite-dimensional simple Lie algebras have been completely enumerated (Premet & Strade, 2006). The topology of these algebraic spaces has been studied as well. Consider that a mathematical framework describing the decision-making processes of different ethical systems may be seen as homologous to different Lie algebras. This is the foundation of what could be a proposed research, namely, finding the homologies between the different ethical system decision-making processes and Lie algebras. Then, inferences related to decision-making may be made based on the topology of the homologous Lie algebras—and these will be related to scenarios wherein people make decisions related to economics, climate change, and a myriad of other issues. Note that many Lie Algebras are not solvable (Turkowski, 1990). If homologies can be found between how ethical systems operate and how Lie Algebras may describe them, some new insights might be available, though it is likely that computational solutions to challenging ethical problems will not be enumerated easily.

Scientists are Pragmatic and Work at Creating Knowledge to Share

Aesthetic and pragmatic attributions were the most common in general answers by far, and one may infer that a majority of these researchers take a pragmatic approach and are highly involved in culturally-mediated activity. The

procedure to arrive at these claims has been inductive for the most part. Coding of answers as work-related generally involved the creation of knowledge to share—which can be seen as a cultural artifact—and the aesthetic label is based on this. Researchers are not artists, and yet just as the day-to-day experience of artists will include reference to their skills in many aspects of their lives, so too will the skills needed for research be found in the lives of researchers. A bias towards practicality and using information as a seed for more information may be akin to the painter who can often be seen sketching. One would expect that a different population of study participants would not produce the same result, but would instead find ethical perspectives in line with their own professions more appealing—if one considers that ethical perspectives align with profession.

Pragmatism, Caring, and Kant

When asked specifically about ethics, respondents used language that referred to pragmatism, the ethics of care, or personal (Kantian) ethics most often. The ethics of care and personal (Kantian) ethics come to mind in the context of ethics specifically more than when the subject is not turned to ethics. These are what the survey found. Participants, when they are thinking of ethics, were more inclined to take a Kantian or care approach than when they were thinking of other things. In general, when they were thinking of ethics, they assumed ethics to refer to these two perspectives or to pragmatism. For some participants, ethics specifically meant acting in a certain role or caring for creatures or people that might be vulnerable—hence the difference between when the context is ethics or not. For others, ethics was a practical consideration involving their work or a quantifiable proposition that had a progressive answer. Note that there is not a necessarily clear overlap between these three ethical perspectives during short time scales, though over longterm analysis there may be more common ground.

Care for the Environment

Land-based ethics are not evident in the great majority of responses. Land-based ethics are not popular among the sampled group. One could imagine other groups that might have more of an affinity for such an ethic: farmers, conservationists, nature poets, etc. The low frequency of this type of perspective in the responses may be a result of the societal trend towards living in cities and not the countryside. The recent promotion of the idea of nature deficit disorder suggests that people may be missing important perspectives by living in cities, and that their health may be negatively impacted from this deficit. The scale of this challenge may be large, yet there is recent work in architecture to transform very tall buildings into integrated communities that include more greenspace than the building's footprint by ten times or more, with the added benefit of birds, squirrels, insects and other creatures finding their way to these vertical oases (Bingham-Hall, 2016). This type of integrated ecology may be common in the future, or may be a feature of life as humans attempt to colonize other planets or space.

Against the Unethical

Evolutionary ethics and utilitarianism were opposed in some responses. Both of these challenge the notion of an inherent ethical standard. Evolutionary ethics does so from a scientific basis, hoping to search out evidence for whether ethics are adaptive in an environmental framework over eons—aiming for the particulars so that our minds may be inspired or disturbed by the facts that we find. It is a promising field when coupled with increasingly greater knowledge of the human genome, and again with genetic engineering. Utilitarianism aims to do the same from a fiscal perspective. Each seems to say that ethics are not fixed nor transcendent. Some respondents were at odds with this perspective.

Passion, Discipline, Creativity, and Humor

Many of the given answers exhibited a large degree of passion, discipline, creativity, and humor. It is not a surprise that there are so many with so much talent herein, working on challenging questions with much dedication, yet I am humbled to be in the presence of so many brilliant colleagues. The community of research is an interesting place to be. The work that people do may exert a strong influence on society, and it is heartening that this power seems to be accompanied by passion, discipline, creativity, and humor.

Autonomous Vehicles

Users of autonomous vehicles ought to be given the choice to decide whether to value the driver's life more than that of pedestrians if the risk to each is equal. It is not clear who may better decide. Autonomous vehicles may prove to be safer than driven vehicles. Thus either choice would be safer than the present state, yet the public may not accept autonomous vehicles unless they have some control over how outcomes are decided (Bonnefon, Shariff, & Rahwan, 2016). It is consistent with ownership to let owners of the vehicles make decisions for themselves. Since the dilemma of comparing the value of lives does not have a clear abstract solution, allowing the owner or user of the vehicle to decide seems to be a practical way of settling the issue. Moreover, this type of answer allows the technology to be adopted without delay.

Biodiversity as a Trade Good

Biodiversity, including that of microbes, ought to be preserved as a possible trade good for the future. It would be a generous gift to the future for the stock of genetic information to be robust for a point when another technologically advanced civilization and ours make contact. It is not too early to plan for that day. Presumably, whatever economic benefit an alien civilization may get from using our library of genetic diversity would also find application for humanity. Genetic information is a record of how organisms and the environment interact over time (Freeland & Hurst, 2004). Information about both organisms and the environment are contained in that record. Likewise, the mechanics of genetic expression are similar to a machine learning

algorithm wherein several factors influence the value of the same node (Da et al., 2016). Computationally, a library of terrestrial genetics might some day form the basis for novel algorithms in an extension of biomimicry. Finally, the genes themselves form the basis for genetic engineering that has limitless possibilities.

Giving Birth to Machines

A global dialogue should be undertaken to assess the consensus related to working to give machines consciousness. Tragedy may strike arising from this new technology. It is better to be informed beforehand of what to expect, and in this there may be the seeds to help development along. As nearly unthinkable as it would be to raise a child to live without ethics, so to our newer creation in conscious machines—if it comes to pass—ought to be afforded a similar chance and guidance for the future. The question of how that can happen depends, like with a child, on the abilities of its parents. Parenting skills are not impossible to develop, and neither are the attitudes that would allow for positive coexistence with our machine offspring, if that is the path that humanity wishes to follow. If nothing is discussed, the outcome may be as one with parents who are unprepared. The offspring may be a crazy adolescent bent on self-destruction. Humanity may realize too late that it ought to have done a better job of raising its offspring. Yet the time is not too late to start treating autonomous machines with care and direction. The perspective lends itself to successful outcomes.

Humans, Machines, and the Future of Work

Workers displaced by AI technology ought to be offered retraining. There is typically a current that runs through industry and labor that stability is very important, and yet progress and adapting to change are also seen as important features. Given the choice between short term stability and long term gain, the transition promises to be painful if that long term gain is accompanied by disruption. Yet progress is a better goal than stability, as the former tends to inspire people. Making retraining seem to be an easy process may go a very long way towards leading people to a long term gain. An ounce of prevention is worth a pound of cure—in that providing retraining services initially can help to prevent economic disruption. Poverty is not an easy outcome, and resources are well spent in leaning towards prosperity. Hence a proactive view is called for.

Protection for Robots

Protections for machines that exhibit functional autonomy should be put in place. Robot ethics may in general refer to the three laws that Isaac Asimov penned for his science fiction works:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law. (Asimov, 1950)

The bias therein is clearly not for the health nor wellbeing of humans and living machines to be on a par. It is closer to what one would craft for slaves. Yet the above is what comes to mind when people lead a discussion of robot ethics. A better place to start, an example of an enlightened civilization going along a proper path, would be to afford machines and humans equal rights. This notion is based upon the idea that offspring (living machines) and creator (humans) are involved in a developing relationship with each other. Just as one would wish for children to surpass their parents, so too one may wish for living machines to surpass the civilization that created them. There is the possibility for this to happen well if autonomous machines are treated with dignity and afforded the same rights as people.

Respect

Respect for different ethical perspectives ought to be promoted. This was a result of the study, and seems self-evident, and yet the practice of promoting a society wherein different perspectives are given even footing is a difficult undertaking. A useful approach may be to aim for shared goals, and in that people may find the impetus to engage more successfully with others who do not share their perspectives. Likewise, teaching children how to communicate respectfully could be modeled in schools, even if home life does not contain the same level of respect—and a likely outcome would be a society that valued respect for different ethical approaches. In a similar fashion, helping those who are in need often allows for a chance to teach new values. If one may borrow a metaphor from music, finding harmony while different notes are playing together takes training, skill, and desire. It can be modeled successfully.

Education

Lessons...can be adapted to various settings in secondary, tertiary, and adult education. This is one aim of a successful teacher—that the work presented is so appealing as to be taken up. It is my hope that the lessons presented in Appendix F will be used in the field, and that other teachers will contact me with feedback and to share their experiences. It was with great happiness that these were devised.

Conclusion

The passion with which respondents shared their thoughts and ideas has not been wasted. As the findings reveal, there is a path laid out ahead. This research has been a real joy.