

# The Social and Conceptual Organization of Synthetic Biology Ethics

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## 1 INTRODUCTION

The field of synthetic biology, still in its early stages, has largely been driven by experimental expertise, and much of its success can be attributed to the skill of the researchers in specific domains of biology. There has been a concerted effort to assemble repositories of standardized components [3, 7]; however, creating and integrating synthetic components remains an ad hoc process. Additionally, many of the ethical issues concerning the re-purposing of living organisms and their biological processes for processes in the chemical engineering, pharmaceutical, and allied industries remain open areas of philosophical research and social discourse.

The Synthetic Biology Knowledge System (SBKS) is a repository system designed to aid synthetic biologists by interlinking the synthetic biology literature through the application of ontologies. While many of these linking tasks are concerned with DNA/protein sequences, the organisms they are cultivated in, or chemical products of cellular processes, it is equally important to interlink the various ethical issues that concern the tailoring biological life in the form of bacteria and yeasts for participation in industrial processes to consider. Thus, an additional linking task for the SBKS is to link pertinent bioethics articles to biological entities, processes, and products that are central to the research of synthetic biologists. In this paper, we make a preliminary analysis of the state of the ethical discourse in the burgeoning synthetic biology discipline.

## 2 DATA AND METHODS

The data come from the Web of Science, and we focus in particular two corpora. The first consists of literature from synthetic biology as a field in general, and the second consists of a subset that discusses ethics and ethical implications of synthetic biology work. There exists a well-established focus on iterative strategies for defining interdisciplinary fields [4], and a burgeoning literature applies established approaches to synthetic biology [3, 6, 7]. Shapira et al. [7] conducted an extensive review of search strategies to extract synthetic biology publications, detailing the consequences of all query inclusions and exclusions made by previous

literature; we employ their query, which was verified by multiple practicing synthetic biologists.

## 3 RESULTS

### Synthetic Biology

We quickly review the findings of the entire synthetic biology field. The field delineation strategy mentioned above produced 15,152 publications between 1900 and 2019.<sup>1</sup> The earliest publication meeting the selection criteria was in 1913. After 1990, one observes an abrupt increase in texts produced and an exponential increase starting around 2000. Looking at the keywords listed by authors, the top two are by far “synthetic biology” and “metabolic engineering”; other top keywords include *e. coli*, “systems biology”, “protein engineering”, and “dna”. The top three fields represented in synthetic biology publications are biochemistry and molecular biology, biotechnology and applied microbiology, and biochemical research methods; the top three publication outlets are *ACS Synthetic Biology*, *Nucleic Acids Research*, and *PNAS*. Keywords, fields, and journals related primarily to ethics and the social implications of research are notably absent from even the top 20 keywords, sub-fields, and publication outlets.

### Synthetic Biology Ethics

The ethics corpus contains 572 publications between 1993 and 2019. Figure 1 visualizes the number of publications per year in this period. A key finding is that the growth starting in 2010 resembles that of synthetic biology more generally starting at 2000; there appears to be a ten-year lag before ethics became a focal topic within synthetic biology.

A correlated topic model (CTM) using stemmed terms [1] suggests that there are nine distinct topics within synthetic biology ethics. Figure 2 plots the proportion of the corpus devoted to each of these nine topics and provides the five most distinctive keywords for each topic. The clustering of the five keywords results from the explicit modeling of correlations among them. One notable finding is that no single topic dominates synthetic biology ethical discourse:

<sup>1</sup>We exclude 2020 because the year is not yet complete.

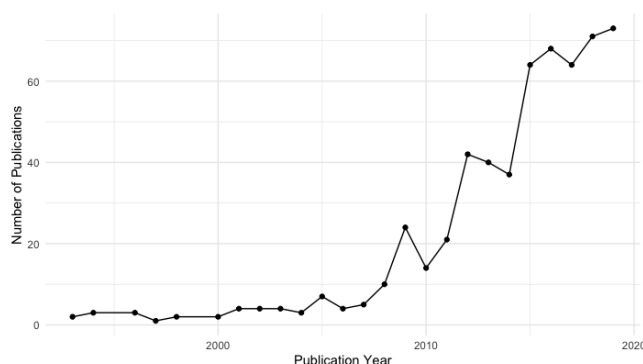


Figure 1: Yearly number of ethics publications

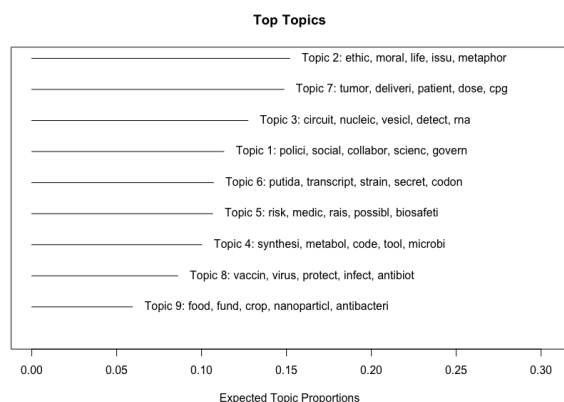


Figure 2: Proportion of topics in ethics corpus

the most prevalent topics each constitute just above 15% of the corpus, and there is a relatively steady decline in prevalence to the least popular topic, which constitutes 6-7% of the corpus. One may see abstract discussions, for example, in Topic 2 that is more philosophical and in Topic 1 that is more political. Topics 5 and 9 appear to occupy a middle ground (re: abstractness), as they discuss medical and food safety, respectively. Other topics, such as 3 and 4, seem to be more focused on concrete synthetic biology practices.

Our final point pertains to the social structure underpinning synthetic biology ethics. Figure 3 plots the number of unique authors and addresses per year. Following the trend from Figure 1, there is a sharp increase in both the unique number of authors and institutions in the synthetic biology publications. One sees in a similar dramatic increase in the fields producing these publications.

These trends suggest that ethical reflection within synthetic biology is at a unique point in its development. “Invisible colleges” [2, 5] describe a form of social organization in new fields where a core set of intellectuals organizes the activities underlying the new field. We conducted a detailed

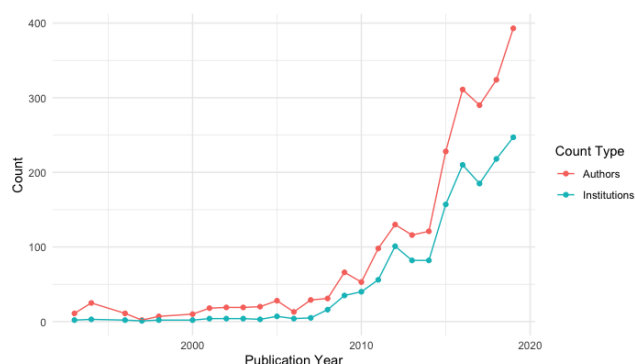


Figure 3: Unique authors and addresses producing ethics publications each year

network analysis of relationships between authors and institutions (to be shown in presentation/poster). Synthetic biology tends to resemble a field transitioning out of an invisible college structure. A core community between collaborators still dominates the field, but this community is rather large and is supplemented by several other communities. Institutions—connected when researchers from each collaborate—are organized into four rather distinct groups: one consisting mostly of U.S. institutions, another consisting mostly of European institutions, a third of largely Chinese institutions, and a fourth of primarily Japanese institutions. However, synthetic biology ethics remains dominated by a central set of institutions, and authors within this ethics network tend to collaborate only with a small number of other authors. The SBKS and related knowledge systems should incorporate the diverse topics we have identified and the texts from the distinct social and institutional communities.

#### 4 ACKNOWLEDGEMENTS

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