# Sustainability and Anticipatory Governance in Synthetic Biology

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## ABSTRACT

*A prominent imaginary of synthetic biology is the sustainability of bio-based technologies. In this paper, the authors discuss various reports, papers, and activities in synthetic biology in relation to a core set of principles of sustainability, paying particular attention to the concept of "prudent vigilance" as introduced by the report by the U.S. Presidential Commission for the Study of Bioethical Issues. The authors introduce two additional concepts – anticipatory governance and transformational sustainability science – and outline an approach for systematically incorporating sustainability considerations into the development of synthetic biology that addresses the challenges and opportunities presented by the field in a more robust way than prudent vigilance. The authors conclude that an opportunity exists to shape synthetic biology toward sustainable outcomes and make recommendations for how research funders might seize this opportunity.*

*Keywords:* *Anticipatory Governance, Bioethical Issues, Prudent Vigilance, Research Funding, Synthetic Biology, Transformational Sustainability Science*

## 1. INTRODUCTION

The front cover of the program for the recent 'Synthetic Biology 5.0' conference states: "Our mission is to ensure that the engineering of biology is conducted in an open and ethical manner to benefit all people and the planet" (BioBricks Foundation, 2011). As with many of the prominent imaginaries or visions of what is to become of synthetic biology in the future, this mission statement aligns quite clearly with goals of sustainability. But despite the prominence and prevalence of such sustainability-oriented visions, there is currently remarkably little robust discussion of how synthetic biology might pursue sustainability or precisely what kind of outcomes it could contribute to.

In this paper, we examine some of these imaginaries through an overview of how various reports, papers and activities in synthetic biology address sustainability. We discuss these in relation to a core set of principles of sustainability that can be derived from the literature. Our review of the connections proposed between synthetic biology and sustainability pays particular attention to the recent report

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by the US Presidential Commission for the Study of Bioethical Issues, which offers an extensive discussion of a concept introduced as "prudent vigilance" that in fact has a great deal in common with sustainability (as spelled out in the core principles). We then introduce two additional concepts – anticipatory governance and transformational sustainability science – and through these, outline an approach for systematically incorporating sustainability considerations into the development of synthetic biology that addresses the challenges and opportunities presented by the field in a more robust way than prudent vigilance. Finally, we argue that since synthetic biology is still in its early stages, there is an opportunity to shape its development towards sustainable outcomes, and we make recommendations for how research funders might seize this opportunity.

## 2. SYNTHETIC BIOLOGY IMAGINARIES

In the introduction to a collection of essays on the "technoscientific imaginary," Marcus (1995, p. 4) describes the imaginary as looking "to the future and future possibility through technoscientific innovation but [being] equally constrained by the very present conditions of scientific work." As synthetic biology is an emerging field of technoscience with so much more to be planned and performed, the imaginaries associated with it play a particularly important role. Many synthetic biology imaginaries draw on notions of sustainability, and we find these imaginaries to be as diverse as scholars' and practitioners' understandings of synthetic biology and sustainability themselves.

Among the more curious and ambitious of these imaginaries is the idea that synthetic biology might act in the service of sustainability by replacing lost biodiversity, and could even to take us beyond what is found in nature to develop new biodiversity. For example, some synthetic biologists argue that nature's canvas is limited by the contingencies and path-dependencies of evolution, and that with their technical powers and imagination they could eventually restore damaged portions of the canvas (for example, by restoring to life extinct species like mammoths) or even enlarge the canvas (by devising species new to nature) (Deamer, 2008; Bedau & Parke, 2009). Similarly, Poste (2007) talks about how synthetic biology will enable us to explore 'biospace,' the immense realm of mathematical possibilities for biological diversity that has been neglected by evolution.

A range of more speculative synthetic biology futures (perhaps closer to science fiction) have also been voiced and tie into discourses of sustainability. For example, there are discussions of how synthetic biology might enable us to grow houses rather than build them (Joachim, Greden, & Arbona, 2008), and of how living cells could be used to construct more sustainable buildings (Armstrong & Spiller, 2010). Speculative designers Ginsberg and Pohflepp have imagined the possibility that synthetic biology might result in a future where goods are transported in the form of seeds that grow into desired commodities, in this way greatly reducing freight costs (Pohflepp, 2009). In line with a common science fiction trope, NASA is exploring the possibility of giving Mars its ecosystem back through synthetic biology (or introducing a new ecosystem if it turns out Martian genomes cannot be reconstructed) (Almeida et al., 2011), and some envision efficient interstellar travel by sending the genetic instructions for recreating Earth-like environments and their inhabitants – even people – to planets orbiting distant stars.

Of course, critiques of these imaginaries also exist. The vision of biodiversity presented above focuses squarely on genes rather than broader habitats and ecosystems. Resurrecting a mammoth might be seen as a trivial achievement without, for example, resurrecting a larger population or community of mammoths, along with their associated grasslands, foodstuff, predators, parasites, etc. Critics also maintain that since synthetic biology would produce life forms that have no evolutionary or ecological history – and thus would not fit into the appropriate evolutionary and ecological niches – they