

The monster and the polar bears: Constructing the future knowledge landscape of synthetic biology to inform responsible innovation

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Nearly two centuries ago Mary Shelley's *Frankenstein* envisioned with prescience the future of health innovation and technology. Shelley's tale of the ambitious doctor, Victor Frankenstein, who generated near-human life, "the Monster", with unintended consequences helped inspire the field of bioethics to attend to issues such as the philosophical and moral standing of humans, machines, and their novel interactions. But since Frankenstein's Monster was left to perish at the North Pole, few, if any, have stopped to consider what impact this might have had on the arctic ecosystem, the iconic polar bears (ever the image of man's recklessness), or the local Inuit communities. Innovations in health technology and health systems have considerable implications for the sustainability of broader socio-ecological-technical systems, which extend beyond debates on the morality and ethics of individual patients and doctors. As the bicentennial of *Frankenstein* approaches, advances in synthetic biology are drawing attention back to health innovation and challenging previously accepted moral and ethical boundaries. Attention should also be paid to how synthetic biology may redefine social-ecological interactions and shape visions, expectations, and fears about the future. The promise of synthetic biology for health is based on Western notions of ideal physical health for the individual, but that ideal does not necessarily scale up to communities or society, nor does it translate to social-ecological system wellbeing. It is critical to understand whether the practice of synthetic biology research and its implications for discrete groups (doctors, patients, insurers) meet established standards – the questions inspired by *Frankenstein* centuries ago. But now is also the time to start investigating whether synthetic biology can contribute to or hinder progress toward sustainability goals from a broader social-ecological-technical systems perspective.

Considering the future contributions of synthetic biology requires first anticipating what may come from innovations in the field. To anticipate is not to predict, but rather to seek out pieces of the future that inform how one acts today (Guston 2013). Knowledge about the future is constantly being socially constructed by a wide diversity of special interests; for emerging technologies, these interests are often scientists, product marketers, and issue advocates. This breadth of knowledge, having distinctly different ontological and epistemological characteristics constitute a multi-dimensional and pluralistic *future knowledge landscape*, which is continuously reformulated and can be enacted to inform present-day actions and planning efforts (Withycombe 2010). So while it is not possible to know exactly what the future holds, one might look at a diverse and broad future knowledge landscape, reflect, and prepare for different futures. Scenario construction and visioning are two anticipatory methods commonly used to construct future knowledge. Such construction is usually done in relative isolation with minimal engagement with other ongoing or past future knowledge construction processes. In these cases, only a small portion of the future knowledge landscape informs decisions—a move from tunnel vision to funnel vision. A full picture of the future knowledge landscape is needed for responsible innovation in synthetic biology, where the very building blocks of life are altered or reassembled. A number of anticipatory activities have been undertaken to examine the future of human health, health systems, health technology and even synthetic biology, specifically. By investigating anticipation around these themes, a rudimentary future knowledge landscape of

synthetic biology can emerge. This would be an important first step in thinking comprehensively about the future of synthetic biology to inform responsible innovation in the field.

Mapping the future knowledge landscape for synthetic biology can serve as the basis for answering several important questions, including: who is shaping which pieces of synthetic biology's future; what are the values imbued in those futures; and what large-scale socio-ecological-technical transformations may arise from those futures? Sustainability provides a framework to analyze what is emphasized in the future knowledge landscape and what is marginalized or absent (like the polar bears). The future knowledge landscape can also be assessed against normative sustainability criteria including livelihood opportunity, human flourishing, and socio-ecological integrity across intra- and inter-generational scales. Such analysis and assessment are critical for developing anticipatory capacities among scientists, policy makers and the broader public whose tax dollars help fund research and who (or perhaps their descendants) will ultimately live with the consequences of innovations in synthetic biology.

At first glance, public as well as scientific discourses on the future of synthetic biology appear to coalesce around extreme promises and perils for humans. This is not uncommon for emerging technologies. Recent bibliometric analysis by Youtie and Shapira (2014) on the future of synthetic biology concludes that the discourse predominately reflects historical approaches to bioethics. Techno-ethical scenarios are also an important part of the scientific dialogue on the future implications of health innovation, while socio-technical systems including physical infrastructures, demographics, as well as the politics and power therein are infrequently referenced. So while bioethical work continues to attend to the individual (e.g. patient rights) and professional societies (e.g. doctors), there is limited understanding of the future implications of synthetic biology for the complex socio-technical systems that encompass health innovation, let alone for social-ecological systems, where there may be potentially significant implications for sustainability. A full literature review is needed which includes a document analysis, with grey literature, focusing on the future of synthetic biology and health innovation more broadly. At present it appears that the future knowledge landscape of synthetic biology specifically, but also health innovation more broadly, is not fully developed enough to inform responsible innovation. Additional future knowledge is needed to fill critical gaps in the future knowledge landscape, but this knowledge must be co-constructed with new and different perspectives.

The construction of future knowledge is often the purview of the powerful—there are future makers and future takers—giving a distinct perspective to the future that possibly diminishes or ignores other important perspectives. Future scenarios of synthetic biology should be constructed, paying particular attention to unexplored areas of the future knowledge landscape, including the impact of synthetic biology on the broader public, marginalized groups, future generations and social-ecological systems. This requires transdisciplinarity (generating knowledge with communities of practitioners and laypersons) to draw upon multiple perspectives with the goal of broadening the future knowledge landscape into new territory. This also requires tools that encourage divergent thinking and inspire creativity in thinking about the future. To return to *Frankenstein*, a research agenda on the societal aspects of synthetic biology should consider the moral and ethical implications of the Monster as well as the human and non-human life he encountered, which might be forever altered. The aim of such a research agenda would be to bring anticipation closer to decision-makers shaping synthetic biology, construct a broader future knowledge landscape for the field, and contribute to the theory and practice of responsible innovation and sustainability.

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