Synthetic biology: taking a look at a field in the making

Nicole Kronberger

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This special issue assembles four articles and a commentary dealing with the emerging field of synthetic biology. "What's in a name?," *Nature Biotechnology* asked in a late 2009 feature. The responses of the twenty interviewed experts highlight that synthetic biology comprises many different projects, approaches and definitions. "If you ask five people to define synthetic biology, you will get six answers," one of the interviewees states (p. 1073). In fact, the term synthetic biology is not new but about to celebrate its centenary; it was coined in 1912 by the French chemist Stéphane Leduc (de Lorenzo and Danchin, 2008). However, it recently gained publicity when selected as an umbrella term for a newly forming academic field. The First International Conference on Synthetic Biology (SB1.0) was held in 2004 and since then the term has rapidly gained ground in academia, business and policy circles.

But what is synthetic biology? In 2005 the European Commission convened a high-level expert group to define and examine the new development. The report begins by defining synthetic biology as "the engineering of biology: the synthesis of complex, biologically based (or inspired) systems which display functions that do not exist in nature. This engineering perspective may be applied at all levels of the hierarchy of biological structures – from individual molecules to whole cells, tissues and organisms. In essence, synthetic biology will enable the design of 'biological systems' in a rational and systematic way" (European Commission, 2005: 5). With synthetic biology, the conceptual tools and language of engineering become the actual method for approaching biology so that engineering now is more than an analogy, as it was for genetic engineering (de Lorenzo and Danchin, 2008).

Synthetic biology represents an interdisciplinary endeavour with contributions from biology, biotechnology, engineering and computing. Both based on the encyclopaedic knowledge of the post-genomic era and with the help of computer power, the challenge becomes "programming" standardised biological parts to create functional systems. Such "designed life," for example, shall make it possible to produce new drugs, vaccines or biofuels, or to facilitate the bioremediation of toxic chemicals. The very first products of synthetic biology are approaching market reality but most applications might take time until they are suitable for commercial exploitation (Kwok, 2010).

Although the field is unified by a name, some basic questions remain unanswered. For example, scientists disagree whether synthetic biology should be seen as a new development or as a convergence of older streams of scientific inquiry and practice. Is it really a paradigm change, as some claim, or is it just a rebranding of genetic or metabolic engineering? Is synthetic biology's agenda about knowing and understanding (as is typical for science) or is it about doing and constructing (as is typical for engineering)? Does synthetic biology really offer the potential for incredible progress or is it just "hype" and a useful way to attract

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funding and investor interest? Will synthetic biology succeed in delivering the promised solutions to pressing medical, agricultural, energy-related and environmental problems? Do the features of the biological substrate make synthetic biology different from other engineering disciplines? Can engineering tame the complexity of life? What will be the intended and unintended consequences? And what social, legal and ethical questions need to be addressed?

The synthetic biology community is aware that its research has the potential to be controversial. At the Second International Conference on Synthetic Biology in 2006 the participants, with reference to the approach chosen for genetic engineering in the 1975 Asilomar declaration, made suggestions for the governance of the field, emphasising self-regulation. This declaration was met with a critical response from a coalition of civil society organisations, who in an open letter called for a broader and more inclusive public debate (ETC, 2007). While the definition of the field is contested, there seems to be widespread consensus that synthetic biology has important ethical, legal, and social implications. Various stakeholders have discussed issues of control and regulation, but standard-setting is controversial and competing proposals abound. Zhang, Marris and Rose (2011) in a review on transnational governance of synthetic biology identified no fewer than 39 reports produced since 2004 by scientific, governmental and non-governmental organisations. So far the threats posed by synthetic biology have not been considered urgent enough to warrant the formation of new regulatory bodies but there is considerable attention directed at discerning potential indicators of conflict.

At least in Europe, stakeholders fear that synthetic biology might evoke public concerns similar to those of gene technology. When in the late 1990s the first genetically modified (GM) consumer products entered the European market, both regulators and the biotechnology industry had to learn that ignoring public opinion can be risky. The imports of the first GM crops of soya from the USA in November 1996 had been mixed with conventional soya, thereby precluding meaningful labelling. This was perceived as an infringement against the right to choose by consumer and environmental organisations and the event triggered massive public and NGO protests in many of the EU member states. Only a few months later, the debate on biotechnology was further fuelled by the advent of "Dolly the sheep," the first animal cloned from an adult cell. Consequently, the resulting "global controversy" (Bauer and Gaskell, 2002) – involving a broad range of national and international actors and concerns – has become a major reference point in discussions on new technologies. Today, it seems, the wish to avoid another failed GM crop debate still is an important driver for decision-makers in the domain.

For synthetic biology, the development of the internet and the routinisation of biotechnological procedures contribute to making DNA "programmable matter." The production of elementary parts is becoming increasingly quick and cheap, and some fear that the construction of biological entities might soon become so accessible that it can be done by amateurs, giving rise to concerns about so-called "garage" or "do-it-yourself" biology, and "biohacking." In addition, synthetic biology seems to meet an established set of anxieties that emerged in debates on biotechnology in the 1990s. Aside from fears about potential abuse (bio-terror), concerns about unintended environmental damage or health risks (bio-error) are voiced. Ethical questions related to creating life and the status of nature as well as questions on intellectual property complement concerns on biosecurity and biosafety.

Although the papers in this special issue address a wide range of issues, they all take up the question on whether and how the GM debate is relevant for the development of synthetic biology. In what ways are old hopes, fears and experiences relevant for sense-making processes related to the new technology? The question is motivated by several factors. First,

even scientists fail to agree on whether synthetic biology should be understood as something new or a further development of biotechnology. Second, and as described above, the GM debate represents a prominent historical marker that is quickly remembered whenever a new and potentially controversial technology appears. Last but not least, there is considerable overlap in terms of vocabulary, actors and concerns that might make it difficult for different groups of society to distinguish synthetic biology from biotechnology.

Even if the field still is in the making and many questions remain to be answered, actors in public life are pressured to interpret the emerging field. Stakeholders, funding institutions, the media and different segments of the population will approach synthetic biology from very different points of view. While they may or may not be interested in learning about scientific details, these groups are affected by a "pragmatic imperative" that goes beyond epistemic goals (Wagner and Hayes, 2005). All these groups need to position themselves vis-à-vis the new technology and act upon their understanding of the emerging field. While experiences with biotechnology may affect the responses to synthetic biology, the reactions at the same time will be formulated in a context that differs from the one in which biotechnology evolved.

Helge Torgersen and Jürgen Hampel (this issue) depart from a societal conflict model to address the question whether synthetic biology might elicit controversies similar to those of GM crops. The analysis highlights that the constellation of conflict elements is quite different for synthetic biology than for GMOs. The authors come to the conclusion that heated public controversy is not very likely, not least because the need to consider ethical, legal and social issues related to synthetic biology is widely acknowledged.

Lei Pei, Sibylle Gaisser and Markus Schmidt (this issue) examine the role of funding agencies in shaping the future of synthetic biology. In its sixth framework programme (FP6), the European Commission funded 18 projects related to synthetic biology with the intention of stimulating research in Europe. The authors analyse whether and how national funding agencies in six European countries have taken up the challenge in the aftermath of this initiative. How do funding agencies define synthetic biology? Which projects do they fund? Are ethical, legal and social aspects being taken into account? The analysis shows that the situation varies considerably across Europe.

Brigitte Gschmeidler and Alexandra Seiringer (this issue) shed light on how the media approach the emerging field of synthetic biology. They present a content analysis of synthetic biology coverage in German-language media from 2004 to 2009. Media attention has risen over the years, but synthetic biology is hardly a "hot" topic, not least because it is scarcely differentiated from gene technology. The (at least partial) overlap in vocabulary, actors and concerns seems to suggest a continuation of a discourse prestructured by earlier debates on biotechnology. The evaluative tone is ambivalent, oscillating between fascination and precaution.

Nicole Kronberger, Peter Holtz and Wolfgang Wagner (this issue) depart from the often heard claim that there is a need to reach out to the public. So far, as some recent representative survey studies show, the term synthetic biology has hardly entered public awareness. Both in the US (Kahan et al., 2009; Pauwels, 2009) and in Europe (Gaskell et al., 2011), only a small minority has heard about synthetic biology. In 2010, across Europe, 83% of respondents said that they had not heard about the new field. How to reach out to the public consequently remains an important question. A (more or less tacit) assumption often is that conflict can be prevented by providing opportunities for better knowledge and/or engagement. This assumption is addressed in a natural experiment in which different groups of the public are invited to discuss synthetic biology. The results suggest that knowledge and deliberation do not necessarily make people more supportive of the emerging field; rather,

group polarisation may occur. If the public should play an active role in shaping the future of synthetic biology, a discussion on how to conceptualise engagement activities is needed.

Lastly, Matthias Kaiser (this issue) provides a thoughtful comment on the four papers of this special issue. He takes a reflective approach by asking, why worry at all about the possibility of social conflict? Together with other developments such as nanotechnology, synthetic biology might raise the question of whether assumptions formed in the context of biotechnology need to be revised. The issues addressed by Kaiser go beyond the topic of synthetic biology and concern social scientists, STS researchers, and those involved in governance alike.

So, what's in the name of synthetic biology? Even if loosely defined, over the years, the label has created a reality that needs to be coped with by a variety of actors, including scientists, policy-makers, funding agencies, the media, different segments of the population, and the authors and readers of this journal. As the contributions in this special issue show, all these actors participate – more or less actively – in defining and shaping what is in the name. While past experiences, such as those with genetic engineering, seem to be important for its development, synthetic biology's exact future remains an open question. At present, we hope the reader enjoys the issues the authors of this special issue raise here.

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Author

Nicole Kronberger is assistant professor at the Department of Social and Economic Psychology at Johannes Kepler University, Linz, Austria. Her research interests focus on social psychological phenomena – such as stereotypes, risk perceptions, moral reasoning and values – and how these relate to public sense-making processes of technologies. Correspondence: Department of Social and Economic Psychology, Johannes Kepler University Linz, Altenberger Strasse 69, 4040 Linz, Austria; e-mail: nicole.kronberger@jku.at