



ETHICS DEBATES ON SYNTHETIC BIOLOGY IN THE EU

**Lead Authors: Dirk Stemerding & Virgil Rerimassie
Rathenau Instituut**

This report represents Deliverable 5.1 for Global Ethics in Science & Technology (GEST), funded by the European Commission's Seventh Framework Programme under grant agreement 266592. The report has been reviewed and accepted by all project partners.

July 2013

Discourses on Synthetic Biology in Europe

Introduction

Ever since the unravelling of the DNA molecule in 1953 by Watson and Crick, developments in biotechnology have come a long way. After cloning and genetic modification, synthetic biology (SynBio) is expected to mark the new phase in the developments of biotechnology. Although still in its infancy, SynBio is developing at rapid speed and has certainly been embraced by scientists in the European Union (EU). In contrast with for instance the United States, biotechnology has stumbled on fierce resistance in the EU and led to stringent regulation. Therefore, some even consider the introduction of biotechnology in the EU as a failure. So, how has SynBio been discussed in the EU so far? In this report we will provide an overview of how SynBio has been discussed in terms of: *innovation, risk, and power & control*. Furthermore, we will discuss *lay morality*: what expectations and issues have been raised concerning SynBio by voices from civil society and the broader public? Last, we will address the way European *reflective ethics* voices engaged with SynBio. We will start off however, by discussing how the field of (and label) SynBio came about.

Visions of Synthetic Biology

On the 23th September of 2008 two reports on SynBio were presented to two ministers representing the Dutch Cabinet. The first was the report *Creating Opportunities*, a joint report by the Dutch Health Council, the (former) Advisory Committee on Health Research (RGO) and the Royal Netherlands Academy of Arts and Sciences (KNAW). Second, the report *Biological Machines?* about the risks and safety aspects of SynBio, drafted by the Dutch Commission on Genetic Modification (COGEM) was presented. A seeming lack of communication by the ministers prior to the presentation led to a peculiar event. What happened? The minister of Education, Culture and Science, Ronald Plasterk – a former professor in molecular genetics – was the first to give a reaction to the reports and an assessment of SynBio. According to Plasterk there are only minor differences with existing DNA techniques and there is no such thing as a new discipline. He therefore also wondered whether it would be wise to pay excessive attention to SynBio. Due to apparent tight agenda scheduling, Plasterk had to leave right after he gave his response. Also due to tight planning, his fellow minister of Housing, Spatial Planning and Environmental Affairs, Jacqueline Cramer – former professor in sustainable entrepreneurship, with a background in biology – only just had arrived when Plasterk was already leaving the stage. Her assessment of SynBio differed quite strongly from Plasterk's. According to her, SynBio certainly does constitute a new discipline at the intersection of bio- and nanotechnology and may become as revolutionary as ICT. In addition, due to the ethical issues SynBio raises, she also expected a fundamental parliamentary debate (Van Maanen 2008). The event is highly illustrative for one of the on-going debates since the emergence of SynBio: is SynBio a game changer or old wine in new bottles? Prior to going into this question, we will briefly delve into the coming about of the term 'synthetic biology'.

Understandings of synthetic biology

The theoretical basis of the contemporary understanding of SynBio is mostly attributed to Wacław Szybalski, who proclaimed in 1974 that "up to now we are working on the descriptive phase of

molecular biology. [...] But the real challenge will start when we enter the synthetic biology phase of research in our field. We will then devise new control elements and add these new modules to the existing genomes or build up wholly new genomes. This would be a field with unlimited expansion potential and hardly any limitations to building ‘new better control circuits’ and [...] finally other ‘synthetic’ organisms [...]” (From: EGE 2009).¹ Thus, according to Szybalski biology will eventually evolve into a different kind of discipline, in which we shift from describing biology to (re)designing biology. Szybalski’s words turned out to be prophetic, but it was not until the turn of the century before scientists started research under the explicit heading of SynBio, often stemming from researchers not primarily involved in (molecular) biology.

According to Torgersen et al. (2011) the current understanding of SynBio is to a large extent the result of successful framing of the field by three different groups: the BioBricks Foundation/iGEM community at MIT with Drew Endy, the SynBio group at Berkeley with Jay Keasling and last, Craig Venter and the researchers at his institute.

One of the major contributors to the current understanding of SynBio is civil engineer Drew Endy. Endy and fellow researchers at MIT envisioned a true engineering mind-set being applied to biology, by bringing in the design principles *standardization* and *modularization*. This effort eventually culminated into the idea of ‘BioBricks’: standardized interchangeable biological parts, and the highly visible BioBricks Foundation, dedicated to further develop this approach. The group surrounding Endy was also involved in laying the groundwork for iGEM – the international Genetically Engineered Machines Competition – which turned out to be of fundamental importance for the spread of the SynBio gospel. What started as an MIT summer course in 2003, grew from a student competition in which 5 teams participated in 2004 into the full-blown international SynBio competition it is today. In 2012 no less than 190 teams participated, stemming from more than 30 countries.² iGEM’s success is to a large extent based on the Registry of Biological Parts: MIT’s open source online catalogue of BioBricks, allowing them to achieve impressive results in a short amount of time.³

Second, the group of Berkeley’s Jay Keasling also contributed to the framing of SynBio as a new engineering discipline. With financial support by for instance the Bill and Melinda Gates foundation, Keasling had been conducting research on *metabolic pathway engineering* in micro-organisms. In doing so, micro-organisms are essentially being converted into living chemical factories, which may produce all sorts of substances useful for e.g. pharmaceuticals and biofuels. Keasling demonstrated the practical application of SynBio in 2006, by ‘teaching’ yeast to produce artemisinin – a crucial substance for Malaria drugs. Currently, Keasling is well on his way to scale up this approach in collaboration with the company Amyris, which was co-founded by Keasling.⁴

¹ Luis Campos demonstrates that the label ‘synthetic biology’ can actually already be traced back to the beginning of the 20th century. The earliest explicit reference to ‘synthetic biology’ comes for example from Stéphane Leduc’s (1853-1939) book ‘*La Biologie Synthétique*’ (Campos 2009).

² See: http://igem.org/Team_List?year=2012.

³ In 2012 the iGEM team of the University of Groningen took home the grand prize with their biological system which detects meat spoilage. The organism is able to detect the gasses of rotten meat and produce a pigment visible to the naked eye. This allows the consumer to monitor the meat’s condition in real time and prevent unnecessary food waste (<http://2012.igem.org/Team:Groningen>).

⁴ <http://newscenter.berkeley.edu/2013/04/11/launch-of-antimalarial-drug-a-triumph-for-uc-berkeley-synthetic-biology/>.

Also human genome sequencing pioneer Craig Venter made his mark on SynBio. Ever since the turn of the 21st century Venter's team has been deconstructing micro-organisms in order to find the minimal amount of genes a living cell requires. Their aim is to develop a *minimal cell*: a simple and predictable micro-organism, that may serve as a 'chassis' or 'platform' organism, on top of which biological systems can be designed. Venter hopes that this chassis-organism will eventually be the starting point for developing organisms that are able to produce hydro fuels or remove carbon-dioxide from the atmosphere. Although Venter has not yet succeeded in the development of the minimal cell, several scientific breakthroughs were made in pursuit of it, all of which were accompanied by large media attention. In 2010 for instance, the institute drew worldwide attention by announcing that it had built in a fully synthetic genome into a micro-organism (Gibson et al. 2010).

Whilst being in a far more experimental phase compared to the aforementioned SynBio approaches, two approaches in SynBio ought to be mentioned as well, in particular given their highly thought-provoking nature. These are approaches regarding *protocells* and *xenobiology*. In case of the former, researchers aim at creating living (metabolically active) cells out of non-living components in a bottom-up fashion. In case of the latter, synthetic biologists try to reconfigure the very basics of biochemistry of life as we know it, for instance by trying to build in altered or non-naturally occurring bases within the DNA. Hence, the terminology 'XNA'. The earlier discussed approaches regarding standardized interchangeable parts, metabolic pathway engineering and minimal cells are at a far more advanced stage than the research on protocells and xenobiology. Nevertheless, the latter demonstrate that some synthetic biologists certainly have the ambition to create artificial life at one day (Torgersen et al. 2011).

Game changer or old wine in new bottles?

What we have seen so far, is that scientists working under the heading of SynBio are employing novel approaches in order to gain control over the building blocks of life. This novel character of SynBio can thus also be found in the definitions used to describe SynBio. One of the definitions that is often being used, stems from a High-Level Expert Group for the European Commission (2005). Moreover the definition contains the core elements used in other definitions of SynBio. It reads as follows: "Synthetic biology is 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". Synthetic biologists thus apply engineering to biology, in order to (re)design organisms that are useful for mankind.

The reason why asking to what extent SynBio differs from other disciplines is so important, is that if SynBio is old wine in new bottles, there is little need for new steps. However, if SynBio is indeed a game changer, it may also lead to a whole new range of ethical, legal and social issues. According to the European Group on Ethics (EGE) there is no clear boundary between earlier genetic engineering, such as based on the insertion of recombinant DNA into organisms, and SynBio: "the first is the starting point and merges into the second without a clear cut limit" (EGE 2009). Nevertheless, the EGE still finds it legitimate to consider SynBio as a new discipline: "recognition of the complexity of biological systems and the intention to construct an organism with radically new properties may be described as a feature of the new discipline" (EGE 2009). The EGE certainly does not stand alone in this view. Consider for instance the ETC Group, a Canadian based NGO highly critically towards

SynBio. According to the ETC Group SynBio constitutes “the next frontier in the manipulation of life: building it from scratch. They call it synthetic biology” (ETC Group 2007). Moreover, the claim for considering SynBio as a new discipline finds support in considering the rapid pace of developments that are driving SynBio. While earlier recombinant DNA technology for example, had to rely on cutting DNA out of existing organisms, synthetic biologists are more and more less dependent hereon. They are able to use DNA that is – ever more cheaply – chemically *synthesized* by specialized companies, allowing far more greater *complexity* and *rational design*. In this regard, synthetic biologists also profit greatly from the ever increasing knowledge that many genetic functions have been *digitized* by means of gene sequencing. Due to this increased complexity and knowledge of specific genes another trait of SynBio comes into play, namely SynBio allows ‘creating’ micro-organisms that have a higher degree of *orthogonality* (differentness) than in the case of earlier technologies. Eventually (micro-)organisms created by means of SynBio will increasingly become more estranged from what we know from nature, as particularly illustrated by the aforementioned research on protocells and xenobiology (Torgersen et al. 2012).

Given the framing of SynBio, the vast developments in the field, and its potential for addressing challenges in terms of energy production, healthcare and the environment, we conclude that SynBio is certainly not old wine in new bottles. Therefore in the following we will assess what expectations SynBio has raised, but also which concerns have been expressed.

SynBio innovation discourse in Europe

Why is SynBio important? What can the field deliver? What are the opportunities for Europe? What is needed to let SynBio mature into an industrially relevant and socially robust discipline? These are the central questions of an innovation discourse that can be found in a number of documents representing funding initiatives and visions of policy and academic institutions on a European level. In 2003 the European Commission launched a broad funding scheme for SynBio through the NEST (New and Emerging Science and Technology) Pathfinder initiative dedicated to ‘blue sky’ research in the 6th Framework Programme. As part of this initiative a High-Level Expert Group was established which published a report in 2005 with the aim to examine, forecast and describe this new and emerging scientific field, its potential impact and support needs. One of the projects funded by the NEST Pathfinder scheme contributed to the European innovation discourse through the development of a roadmap that was published in 2008 as a guideline towards a European strategy for SynBio in Europe (TESSY). In 2010 two other important contributions appeared. One was an OECD & Royal Society Synthesis Report of an international symposium discussing the opportunities and challenges of the emerging field of SynBio. The other was a Policy Report from the European Academies Science Advisory Council (EASAC), titled Realising European potential in synthetic biology: scientific opportunities and good governance.

NEST: A ‘new and emerging science and technology’ initiative

How is SynBio conceived in this European policy and academic innovation arena? According to the NEST High-Level Expert Group (2005) SynBio could revolutionize the biological and biotechnology industries and maybe even biology as a science. The aims of SynBio at standardization and a division of labour between the designers of basic components and of complex systems are likely to speed up research and development in a much more organised way and pretty much reflect the hallmarks of a mature industrial sector. It will create highly generic capabilities for the use of bio-inspired tools and

processes and thus may be able to realize many of the promises that traditional biotech is still struggling to fulfil in such important areas as biomedicine, synthesis of biopharmaceuticals, sustainable chemical industry, environment and energy, and production of smart materials and biomaterials.

When the engineering of biology becomes easy, reliable and cheap, it will be used not only to solve currently intractable problems at the leading edge of applied science but also for more routine applications that can at present be only speculated about. It is obvious, in the vision of the High-Level Expert Group, that Europe should invest in this area, in order to create the necessary intellectual and physical infrastructures, and capture a share of the valuable intellectual property that is at stake. Funding is needed to support basic research and to foster a community of researchers (particularly among younger scientists) creating a forum for the establishment of clear goals, shared tools and agreed standards. In this context, the Expert Group also emphasizes the need to address ethical and safety concerns from the very beginning, so that future development work can be done in conditions of public trust.

The perceived needs for the field are reflected in the different categories of projects that have been funded by the NEST Pathfinder initiative in the period of 2004 – 2008. Of the 18 projects funded, 7 were in the area of advanced biological (and biomimetic) *systems engineering*, 6 in the area of advanced biological (metabolic) *pathway engineering*, 2 projects aimed at *coordination* through standardization and community building, and another 3 projects aimed at *strategy development* through identification of key stakeholders, regulatory and ethical issues, and road-mapping. The NEST funding initiative served as an important starting point for the development of SynBio in Europe (Pei et al. 2011). It was followed by other European funding initiatives under the 7th Framework programme, including both R&D funding and Science in Society funding for ELSI studies, and a EUROSYNBIO programme supported by the European Science Foundation. It also resulted in a roadmap informing strategy development for SynBio in Europe (TESSY 2008; Gaisser et al. 2009).

A SynBio roadmap for Europe

The TESSY roadmap project indicates the broad range of opportunities offered by SynBio in industrial, medical, environmental and plant biotechnology and discusses the steps that have to be taken over the next ten years to realize its promises. These steps include the construction and testing of biological parts, their integration into complex synthetic systems, the development of a common framework for characterizing and standardizing parts, the pursuance of orthogonality of parts and functions, and the establishment of a solid computational and modelling infrastructure. Other steps will have to promote community building, bringing together competences from different disciplines and fostering transnational as well as transcontinental communication and cooperation, and should address issues of regulation and social and ethical challenges. It is seen as essential for the scientific community to play a leadership role in addressing these issues. Science and technology should not get too far ahead of public opinion and social benefits should be clearly shown.

The development of the TESSY roadmap had the aim to boost SynBio in Europe, to mobilize public and private resources both on the European and national level and to offer strategic guidance in four different dimensions. These dimensions highlight the need for a highly *interdisciplinary approach*, the need for *knowledge transfer* based on joint projects between industry and academia, the need for *funding* supporting both blue sky research, commercialization and studies of ethical, legal and

social issues (indicating a budget for ELSI studies of 5-10%), and the need for *regulation* including technical standards, clarification of intellectual property issues, mechanisms for risk assessment and management, and the development of a code of conduct. A crucially important guiding concept connecting these different dimensions is *integration*, not only at the intersection of natural science, engineering and industry, but also in a broader sense, involving policy makers, societal stakeholders and the public in a continuous dialogue with the aim to develop the field in accordance with public needs and within generally accepted framework conditions.

Growing scientific and policy interest

The international symposium organized and reported by the OECD & Royal Society (2010) brought together various communities – scientific, engineering, policy, public, legal – with the aim to evoke a wide-ranging discussion of the value of SynBio and to explore the opportunities and challenges raised by this emerging field. By highlighting three national perspectives – from the US, UK and China – the symposium also aimed at a richer comparative understanding of national cultures of innovation in order to recognize differences as well as opportunities for collaboration. As key points the report identifies the need to invest in underpinning technologies and to bridge the gap between tools and applications, to create international collaboration in the regulation and governance of SynBio and the need to create opportunities for public dialogue and engagement. Another key issue raised during the symposium concerned intellectual property. The aim of SynBio to develop a cumulative and convergent set of biological parts and modular components involves the risk of patent thickets hindering the ability to do research and commercialize applications. However, while many in the field advocate openness, it is expected that the role of intellectual property will become more and more important as the field grows and enters commercial application.

The EASAC Policy Report (2010) was published in response to meetings and documents organized and published by several member academies in Europe, reflecting an increasing scientific and public policy interest in SynBio. In bringing together these different analyses and perspectives, the report not only spreads a now familiar message about SynBio, but also clearly articulates the values underpinning the European innovation discourse. The value of SynBio is related to its potential to tackle European societal needs and to promote economic growth. It may raise societal concerns but also the global competitive status of Europe. Thus, current strategic investment of EU Structural Funds for innovation must continue and funding for SynBio should be at least as high in the 7th as in the 6th Framework Programme. SynBio will become even more important for the EU strategy for 2020 which emphasizes key drivers that include ‘smart growth’ – developing an economy based on knowledge and innovation – and ‘sustainable growth’ – promoting a more resource efficient, greener and more competitive economy. Moreover, public sector financial support across the R&D continuum might also help to counter any concerns that ‘big business’ will monopolize the outputs. The report concludes that SynBio may make a major contribution to future EU innovation and competitiveness as well as to the understanding of natural biological systems. Indeed, as the OECD & Royal Society report points out, the potential of SynBio is also inherent to the particular nature of the science, freeing the design of biological systems from the process of natural evolution and thus adding a new layer to the power of nature.

A field gaining momentum

In the past ten years SynBio has become the subject of an innovation discourse in which the field gained momentum through the mobilisation of resources and coordinating actions on both the

European and national level. Up to 2007, mainly as a result of the early NEST funding initiative, public funding of SynBio projects was higher in Europe than in the United States (EPTA 2011). The NEST programme was meant to stimulate a research community in Europe, with the aim that national funding agencies should then continue to fund scientific projects in that area. Although the funding situation varies considerably among European countries, SynBio is being supported through national research funds in several countries. The UK is in a leading position as the only country which has established dedicated SynBio funding schemes for R&D and ELSI studies (Pei et al. 2011). In Europe, the SynBio field has taken shape in networks and new research centres and is further supported by ERASynBio, a recently established European initiative aiming at the development and coordination of synthetic biology in the European research area (2012 – 2014). ERASynBio will develop a strategic research agenda with the aim to support the emergence of national SynBio programmes and to lay the ground for transnational funding activities via joint calls in the field.

The European innovation discourse about SynBio has been mainly a science-industry-government discourse, strongly driven by the aim to secure a global competitive edge in the emerging bio-economy. Support for SynBio, however, has been justified and challenged also in terms of other values than 'smart' and 'sustainable' growth. SynBio likewise thrives on the enthusiasm for a new and playful engineering approach to biology, emphasizing a culture of openness, knowledge sharing and social responsibility which also involves do-it-yourself communities inspired by the ideal of a democratized science (Wohlsen 2011). The promise of SynBio 'to add a new layer of power to nature', on the other hand, has been consistently criticized by civil society organisations, notably the international ETC group, for promoting new forms of exploitation of natural resources and the communities that are dependent on them (ETC 2007). From this perspective, the engineering approach of SynBio is perceived as primarily being shaped by commercial values that stand in clear contrast with values of sustainability and global justice.

In the on-going innovation discourse about SynBio such concerns and tensions clearly resound in repeated arguments for public dialogue and engagement and have also been answered in official policies for 'responsible innovation' in Europe, that is, in approaches that consider the needs of science and industry, on the one hand, and comply with the expectations of society, on the other hand (Gaisser & Reiss 2009). In the EU a new FP7 Science in Society funding scheme has been established supporting Mobilisation and Mutual Learning Action Plans (MMLAP) which should involve a wide range of stakeholders and publics in the shaping of innovation and its implications. One of the MMLAP's funded for the next four years focuses on the field of synthetic biology (2013 – 2017).

SynBio risk discourse in Europe

Is it time to think about risks? Time for another Asimolar? These were questions raised by science writer Philip Ball in *Nature* in 2004. SynBio, he notes, is opening up extraordinary possibilities for biomedical discovery and environmental engineering, but it also carries potential dangers that could eclipse the concerns already raised about genetic engineering and nanotechnology. Should limits be set on what is attempted? If so, what should they be and how should they be enforced? And what steps can be taken to ensure that a rogue organization, or even a state-sponsored bioweapons programme does not use the technology to synthesize a dangerous microbe? Ball's questions delineate a discourse of risk which has attended the rise of SynBio from the very beginning. One of the early projects funded by the European NEST Pathfinder initiative was SYNBIOSAFE, a project

aiming at the creation of a framework of safety, ethics and public acceptance, within which Europe's fledgling synthetic biology industry might flourish. Issues of *biosafety* – relating to potential unintended consequences – and *biosecurity* – relating to potential misuse – were also addressed in an Opinion on the ethics of SynBio by the European Group on Ethics in Science and Technologies to the European Commission (2009). These issues again recur in the earlier mentioned reports of the OECD & Royal Society and EASAC from 2010. And, last but not least, these issues immediately led to critical and alarming responses to SynBio from a number of (international) civil society organizations.

Steps that can be taken to minimize risks

In the report of the NEST High-Level Expert Group (2005) it is noted that, as with any other potent advance in science, SynBio has its risks. It is obvious, according to the report, that genetic manipulation of organisms can be used, or can result by chance, in potentially dangerous modifications for human health or the environment. The possibility of designing a new virus or bacterium 'à la carte' could be used by bioterrorists to create new resistant pathogenic strains or organisms, perhaps even engineered to attack genetically specific sub-populations. Thus, the combination of engineering with the possibility of synthesizing whole genomes is clearly problematic. However, there are steps that can be taken to minimize risks. In this context, the report refers to controls and regulations that can be imposed on 'parts suppliers', in particular the companies that provide synthetic DNA sequences to order.

In addition to abuses of SynBio at the scales of organized terrorist groups or even biological warfare initiatives at a national level, there is a danger, as the report points out, of the development of a 'bio-hacker' culture, in which lone individuals develop dangerous organisms much as they currently create computer viruses. Although such manipulations currently require considerable technical expertise and resources, it would be wise to anticipate this development as a possibility since the basic technologies for systematic genetic modification of organisms are widely available and becoming cheaper. How this sort of sociopathic activity can be prevented by the scientific community is not easy to see according to the report, but there is at least the possibility of aiming to 'deglamorize' such activities at an early stage.

The report further notes a pressing need to examine whether existing safety regulations for the management of engineered microorganisms provide adequate protection against inadvertent release of 'synthetic' pathogens, even though it is not obvious that there is any aspect of SynBio that – in terms of risks, abuses and safety measures – is qualitatively different from the way such issues apply to biotechnology and genetic modification. Moreover, whereas the potential risks of a technology as powerful as SynBio must inevitably sound alarming, it is also important with a new technology of this sort to consider the risks, and indeed the ethics, of *not* developing it. One can argue, as the report suggests, an ethical case for developing SynBio as a 'biotechnology that works' for the development of new drugs, particularly ones that might provide effective and affordable treatments for diseases such as malaria that present major health hazards and causes of fatalities in developing countries.

Biosafety as an issue of concern

While the NEST High-Level Expert group puts upfront in their risk discussion the potential for misuse of SynBio, most actors in the European risk discourse mention biosafety issues as their primary concern. In a discussion of the outcomes of the SYNBIOSAFE project, Markus Schmidt argues that "the difference between having enough knowledge to create a new bio-system and having enough

knowledge to fully grasp all possible interactions and its complete set of behavioural characteristics, is exactly what makes the difference for a sustainable and safe development". The ambition of SynBio to radically redesign biological systems thus challenges the state-of-the-art biosafety framework in several respects and requires us to ask if the current GMO risk assessment practice is good enough to cover all developments in the field in the upcoming years (Schmidt 2009).

This sentiment is also clearly expressed in the Opinion of the European Group on Ethics, which observes that the biosafety of SynBio products is heavily debated between scientists and decision makers because absence of clear biosafety data may compromise the reliability of the EU biosafety framework. Under the current regulatory framework, risk assessments of genetically modified organisms compare the altered organism with the natural organism on which it is based, considering the individual traits introduced. By inserting multiple genetic traits from potentially several different donors or using an artificially expanded genetic information system, SynBio may produce organisms which have no comparable counterpart in nature (EGE 2009).

A similar concern was raised in the context of a comprehensive web-based consultation, organized by the SYNBIOSAFE project, in which participants worried about hard to predict emergent effects that may result from the creation of complex synthetic genetic circuits and that may be difficult to deal with in established practices of risk assessment. During this consultation, the topic of 'biohacking' also elicited discussion, especially on how realistic a biohacker scenario was and how biohackers would affect biosafety considerations. Participants concluded that if SynBio's 'de-skilling' agenda would prove successful – making it easier to construct new life forms and enabling more people to design new living systems – a qualitatively new challenge would arise (Schmidt et al. 2008). The OECD & Royal Society symposium report adds to these concerns considerations about how things have moved since Asilomar. The global proliferation and distribution of knowledge makes oversight increasingly difficult and, while the intermingling of disciplines helps SynBio progress, awareness and training in biosafety issues differ across disciplines (OECD & Royal Society 2010).

A view emerging from this risk discourse is that biosafety issues will become more and more relevant as the field of SynBio matures. Accordingly, in its recommendations to the European Commission, the European Group on Ethics asked "to initiate a study on current risk assessment procedures in the EU" (EGE 2009). In the OECD & Royal Society 2010 symposium report reference is made to updates in the US of the current recombinant DNA-guidelines and to a European Commission working group exploring whether existing legislation need updating to accommodate synthetic biology. In the symposium discussions however, one issue was left hanging: "would we recognize the point at which evolving synthetic biology research posed a fundamental challenge to the current regulatory structure, a challenge that could not be met by modifying existing structures?" (OECD & Royal Society 2010).

To be sure, in this discussion there is also a countervailing view, expressed by the EASAC in its Policy Report, that seeking new governance mechanisms is premature. There is, as yet, no consensus, as the EASAC points out, on whether SynBio will be a truly transformational technology and, if so, whether it can or cannot be accommodated within the current regulatory framework. In this light, the report concludes that existing legislation is adequate as long as SB remains an incremental extension of recombinant DNA technology (EASAC 2010).

SynBio as ultimate biosafety tool?

One of the issues addressed in these discussions of risk is SynBio's potential to make biology not only easier, but also safer to engineer. Basically the idea is that the surest way to avoid risks of dissemination and contamination by potentially harmful synthetic species is to construct forms of life "as deviant as possible from that of natural species" (Marlière 2009). In a review article discussing new forms of life as "ultimate safety tool" Markus Schmidt (SYNBIOSAFE) explains why SynBio engineers should embark on the difficult and laborious journey to develop biological systems based on 'XNA' as information carrier not found in nature. In his view, a future of bioengineering which depends on "fast, in-depth and ubiquitous engineering of our own genetic (source) code" will inevitably run into potential public fear and subsequently "regulatory red taping" that could stifle further developments and opportunities. So, "why not switch to another hardware that is incompatible with everything nature has ever created" and construct a "genetic firewall that solves this problem for once and for all?" (Schmidt 2010).

Discussion of these ideas in a recent ESF 'biocontainment' workshop pin-pointed as a major issue the sort of assessments that needs to be done for the release of microbes constructed using non-familiar biochemistry. It will necessarily have to be a risk assessment without natural comparators, evoking concern among workshop participants that something that seems unfamiliar may be looked upon more negatively than something that is familiar, even if the unfamiliar thing is in fact safer for the environment (Garfinkel, unpublished).

Other voices in the debate

While most actors in the SynBio risk discourse acknowledge the need to reconsider established safety practices in the light of potential future developments, they also share a widespread belief that developments in SynBio today still fall solidly into current approaches to risk assessment. There are however other, more stark and critical voices in the international debate. Denise Caruso, an independent policy consultant from the US, argues in "an overview anticipating and addressing emerging risks" that SynBio poses "what may be the most profound challenge to government oversight of technology in human history" (Caruso 2008). She questions whether synthetic biologists can truly claim to know enough about living, reproducing biological systems to design artificial organisms and, more important, to reliably predict their behaviour and effects "once they have been released". The circumstances surrounding SynBio are extraordinary in her view. With hundreds of millions of dollars worldwide already spent or committed to SynBio R&D, companies are driving hard to deliver products for commercial release, while major issues of risk still need to be addressed. SynBio practitioners may argue that they already fall within the purview of existing regulations that govern genetically engineered organisms. Caruso, on the other hand, emphasizes that the process in SynBio is "dramatically different" from modifying the function of an existing organism using the techniques of traditional genetic engineering. So, it is obviously important from her point of view to take action as quickly as possible to improve the oversight and governance of synthetic biology.

Caruso articulates an opinion on SynBio that has also been forcibly argued by a number of international civil society organisations, like the ETC group in its famous Extreme Genetic Engineering report (2007). More recently this position has been reiterated in a report on The Principles for the Oversight of Synthetic Biology, published by Friends of the Earth, the International Center for Technology Assessment and the ETC group in the name of more than hundred endorsing civil society organizations. Standard forms of risk assessment and cost-benefit analyses relied on by current biotechnology regulatory approaches are inadequate, according to the report, to guarantee

protection of the public and the environment. Attempts to develop alternative genetic systems (such as xenobiology, mirror biology or novel amino acids) are not well enough understood to claim they provide safety. Thus, governmental bodies, international organizations and relevant parties must immediately implement strong and comprehensive oversight mechanisms “enacting, incorporating and internalizing” as a basic value the firm *precautionary principles* that are taken in the report as a starting point. Until that time, there must be a moratorium on the release and commercial use of synthetic organisms and their products to prevent direct or indirect harm to people and the environment (FOE, CTA & ETC group 2012).

To what extent are these voices indeed different from widely held beliefs in the SynBio risk discourse? Apart from the alarming tone, many scientists in the field will agree with the idea that *deliberate release* of synthetic organisms should be considered with the greatest care. For the moment SynBio is a contained laboratory affair, but it is true that many of the applications ultimately involve the release of synthetic organisms into the environment. This point has recently been thoroughly discussed in a joint publication of SynBio practitioners and ethicists from the UK (Anderson et al. 2012). Minimum robustness needs to be considerably higher for organisms intended for release into the general environment than for organisms that are to be used in tightly controlled industrial settings, and this creates major scientific and engineering challenges, in particular the need to design robust and predictable synthetic organisms.

Some of the defining properties of biological systems, such as their natural ability to evolve, raise fundamental theoretical problems and, as the authors emphasize, one of the fundamental challenges for SynBio is to account for the uncertain environment that the synthetic organism might eventually inhabit. Thus, the predictability of evolution and adaptation of synthetic organisms is limited and there are further challenges related to our (in)ability to predict the behaviour of an ensemble of interconnected – artificially or naturally derived – modules introduced in synthetic organisms. The authors see it as vital that future design frameworks consider evolution, to ensure that synthetic organisms behave as predicted over longer timescales, and are thus compliant from a biosafety standpoint. Although the precautionary principle may seem a reasonable approach in dealing with these risks, it has a notable problem, as the authors observe, that it seems to be inappropriately insensitive to the benefits of a course of action, or, put another way, to the risks of inaction. Clearly, there is a need for ethical analysis to help determine what level of predictability should be required, and how the possible risks should be weighed against probable benefits.

SynBio power & control discourse in Europe

As observed in the OECD and Royal Society symposium report (2010), SynBio arrives at a time when science’s role and position in society face increased public scrutiny. In this context difficult questions are raised, including: Who is to imagine the future of science? How do we decide which scientific and technological interventions to undertake for society? Who is responsible for the consequences of innovation whether positive or negative? Such issues of power & control are seen as particularly sensitive in the domain of the life sciences, arising even at very early stages of research and innovation. With the promotion of SynBio as a new engineering science of life, the role of scientists, policy makers, regulators and civil society in the *governance* of SynBio risks and innovation has indeed become an early and hot topic of debate. Contributions to this debate come from technology assessment, scholars in the field of science, technology and innovation studies, academic and policy

advisory bodies, and civil society organizations (ETC group 2007, Roco 2008, Caruso 2008, Torgersen 2009, Tait 2009, IRGC 2010, EASAC 2010, Zhang et al. 2011, FOE, CTA & ETC group 2012).

Governance of risks

A major issue in the SynBio power & control discourse is the governance of risks. In a Policy Brief on Guidelines for the Appropriate Risk Governance of SynBio, the International Risk Governance Council points out that there is currently a complex array of national and international regulatory instruments that may be relevant for, or act as precedents for, the regulation of SynBio (IRGC 2010). As we have seen, most members of the scientific community seem to consider existing risk assessment rules still to be adequate. However, as with any rapidly evolving technology, the question is how long the current regulatory toolbox will prove to be applicable and sufficient (Torgersen 2009). How to deal with these imminent questions of risk and who should take responsibility for the regulatory challenges that may result from these risks?

In its Policy Brief the IRGC advocates an approach that seeks to promote a *culture of responsibility* in the life sciences, backed up by legal mechanisms. On this basis, risk assessment of SynBio should be capable of evolving as scientific and technical knowledge expands and as lessons are learned about the most appropriate forms of regulation and governance (IRGC 2010). Other authors have likewise argued for an adaptive and anticipatory approach to issues of risk (Roco 2007): an approach that, in the face of future uncertainty, is best framed “not as a rigid regulatory regime, but as a flexible and evolving *art of governance*” (Zhang et al. 2011). Finding a right balance between professional self-governance and statutory regulation is seen as crucial for this kind of learning approach (EASAC 2010).

A totally different stance on these issues we find among those who criticize SynBio as a strongly market-driven, radically novel technology, challenging current regimes of regulation as a “juggernaut already beyond the reach of governance” (Caruso 2008). From this point of view, a culture of responsibility utterly fails to answer “important questions related to power, control and economic impacts of synthetic biology” (ETC group 2007). Thus, according to the announced Principles for the Oversight of Synthetic Biology, there is an urgent need for ethical and legal mechanisms that require mandatory SynBio-specific regulations and should entail a legally enforceable right of the public to halt dangerous applications (FOE, CTA & ETC group 2012).

Risk, innovation and ownership

Governance systems should, in the words of the OECD and Royal Society Symposium report (2010), not only be sustainable, forward-looking and dynamic, but also *allow* innovation in SynBio to emerge. This point refers to the relationship between regulation and innovation as an important concern in debates about the governance of emerging technologies. The question is whether regulation, apart from its obvious role in managing technological risks, might have indirect and unwanted effects on processes of innovation by creating barriers to entry for new and small companies with innovative ideas. This concern has been raised in particular for SynBio as a science that will have to face strong demands for regulation following from the established governance model for biotechnology (Tait 2009). In this context, the IRGC has advocated *appropriate risk governance* as a concept that is informed by an understanding of how regulatory approaches interact with innovation processes, explaining “the risks of not doing as well as doing” and balancing the interests and values of all relevant stakeholders (IRGC 2010).

Another tension involving different interests and values in the SynBio power & control discourse relates to the issue of ownership of knowledge and its effects on innovation. On this point, both SynBio scientists and civil society organisations have expressed concerns about the ways in which patents in SynBio might inhibit its potential for innovation and foster the monopolization of the field by commercial companies (Tait 2009, FOE, CTA & ETC group 2012). Various schemes have been suggested for supporting the sharing of information in SynBio while maintaining incentives for innovation. However, as the IRGC points out, the claims made for open-source biology still have to prove itself in cases like SynBio (IRGC 2010). Indeed, the ‘unnaturalness’ of its creations may actually make it easier to patent SynBio products, thus adding to their potential for public controversy (Tait 2009).

Public engagement and global governance

The balancing of the interests and values of all relevant stakeholders is mentioned by the IRGC as the cornerstone of an appropriate risk governance approach. However, as the IRGC observes, it is still challenging to find ways of reconciling fundamentally conflicting values or ideologies. Dialogue around shared interests could lead to more creative regulatory solutions that avoid the imposition of a single set of values that unnecessarily constrains the opportunities available to society at large (IRGC 2010). Thus, in the increasingly active risk debate around synthetic biology, there is a strong focus on potential public and stakeholder questions and concerns and how and when to incorporate them into decision making about future developments (Tait 2009, OECD & Royal Society 2010).

However, as becomes clear from the various contributions to the SynBio power & control discourse, the lessons we need to learn are more complex than merely “more and earlier stakeholder engagement” (Tait 2009, IRGC 2010, Zhang et al. 2011). The challenge is not only how to reconcile the goals of delivering public benefits from new technology, avoiding unnecessary risks, and allowing commercially viable activity, but also how to do so in the context of a *globally* evolving science. As both Tait and the IRGC point out, the potential benefits, and also the potential risks, along with the speed of emergence of new developments, make SynBio a prime case for concerted international consideration about its governance in a way that takes into account the interests and values of technology developers, policymakers, regulators and public and stakeholder groups. In a working paper on the challenges of “transnational governance”, Zhang et al. emphasize *cross-borderness* as a central feature of SynBio, both in terms of inter-relations on a global scale, and in terms of increasing interconnections between academic disciplines and industrial sectors. In their view, the feature of cross-borderness ensures that no single group, organization, constituency or regulatory body will have the capacity to oversee, let alone to control, the development of synthetic biology. What is needed is an ‘art of governance’ which seeks to facilitate effective interactions between a range of current and emerging social actors and to encourage these actors, through identifying key questions and pending future scenarios, to get prepared and to explore ways to handle impending and uncertain situations.

SynBio, values and lay morality in Europe

In the foregoing we have focused on the issues that are debated in three SynBio discourses. In this section we will focus on the *values* that are underpinning these discourses and we will include in our discussion the ‘lay morality’ that is informing public debate about issues of SynBio innovation, risk, and power & control. The values that we will refer to in our discussion we have adopted from the

GEST Ethics State of the Art which provides us with an overview of the value systems used at the European level to govern policy, including S&T policy (Schroeder 2012). The following fundamental principles or values have acquired special recognition within Europe: justice, solidarity, equality, dignity, citizens' rights, freedoms and sustainability. To identify these values in the three SynBio discourses we can use the statements of the actors actively involved in these different discourses. For our analysis of lay morality we have to rely on other sources because SynBio did not (yet) give rise to a broader *public* debate in society. This need not surprise us, since public awareness of SynBio as a new emerging science is low. The Eurobarometer survey shows that 83% of European citizens have never heard of SynBio (Eurobarometer Biotechnology 2010). However, there have been some initiatives in Europe to organize public dialogues about SynBio in order to gauge public views and concerns and to engage citizens and stakeholders in an informed debate on the public value, ethics and potential applications of SynBio.

In the following we will first of all discuss the values that can be identified in the previously described discourses, which we consider as the *active* SynBio debate mainly involving actors from European science, industry and government, and more incidentally also actors from civil society. We then supplement our findings with data about public voices that have been tapped by surveys or organized dialogue events (or have been raised by civil society organizations). We will use data from three main sources. Our first source is a set of public dialogues on SynBio held in the United Kingdom (RAE 2009, Battachary et al. 2010).⁵ Another source is the Meeting of Young Minds, a SynBio debate organized by the Rathenau Instituut, involving Dutch political youth organizations (varying from left and right wing, to green and Christian) and iGEM participants (Rerimassie & Stemerding 2012).⁶ Finally, we will use the Eurobarometer survey of 2010 to occasionally supplement the information with additional quantitative data.

Innovation, values and lay morality

SynBio innovation is motivated by its potential to tackle European societal needs and to promote smart and sustainable growth. In addition, investments in SynBio are seen as a means to capture valuable intellectual property and to raise the global competitive status of Europe. Thus we find in

⁵ In the UK two public dialogue activities were organized consecutively. In 2009 the UK Royal Academy of Engineering (RAE) commissioned an exploratory public dialogue "*to explore informed and uninformed perceptions of and attitudes to synthetic biology in the UK*" (RAE 2009). The report *Synthetic biology: public dialogue on synthetic biology* (RAE 2009) presents the findings of the dialogue activities: two focus group sessions with 16 members of the public and a telephone survey of 1.000 adults. The Biotechnology and Biological Sciences Research Council (BBSRC) and the Engineering and Physical Sciences Research Council (EPSRC) also commissioned a series of public workshops and stakeholder interviews on SynBio in 2009, which led to the report *Synthetic Biology Dialogue* (Bhattachary et al. 2010). The dialogue involved 160 members of the public, through three workshops in London, North Wales and Edinburgh. In addition, 41 stakeholder interviews were also conducted.

⁶ Due to the growth of iGEM the organization decided regionalize the competition in 2011. The European/African pre-round (jamboree) was to be held in Amsterdam. In order to provoke more debate on SynBio in the Netherlands, the Rathenau Instituut collaborated with the regional iGEM committee to organize youth debate between future politicians and future synthetic biologists. Interestingly, the iGEM competition explicitly invites participants to address societal and ethical dimensions of SynBio, the so-called *human practices* component of the competition. Henceforth, the future synthetic biologists were represented by the iGEM participants. The future politicians were represented by Dutch political youth organizations. The Rathenau Instituut found seven PYO's willing to formulate a political view on SynBio and enter into debate with the iGEM participants and each other. The Rathenau Instituut assisted the PYO's in their opinion making by, e.g. providing information and an expert meeting.

the innovation discourse, on the one hand, motivations referring to the public good and the value of *sustainability* and, on the other hand, motivations referring to commercial and economic interests in a world of market *freedoms*.

When taking a look at the organized UK public dialogues we also find high expectations about SynBio innovation. Participants were “astonished” by the ambition and imagination of synthetic biologists who hope to address grand challenges facing society such as global warming and global health issues. The prospect of being able to achieve these goals is a significant factor in the public appreciation of SynBio research (Battachary et al. 2010). In the Dutch Meeting of Young Minds we see similar hopes. For instance the Young Democrats turned out to be a true supporter of SynBio as becomes clear from the following statement: “in order to solve the grand challenges of our times, we need technology. Synthetic biology can play an important role in addressing global food shortages, our future energy supply and environmental pollution”. The Young Socialists agreed: “Even if it involves more risks, it might also lead to more well-being” (Rerimassie & Stemerding 2012). In terms of lay morality, SynBio innovation is clearly highly valued for its potential contributions to sustainability and the public good.

In this respect, civil society organizations are more sceptical and critical about what they see as the hope of synthetic biologists for quick ‘technological fixes’. In their view, technologies tend to maintain or even reinforce the socio-economic and political structures that are the cause of the problems that synthetic biologists hope to solve, while at the same time introducing new risks (Stemerding et al. 2009). Concerns about the fallacy of technological fixes were also raised by some of the political youth organizations during the Dutch Meeting of Young Minds. For instance, the animal welfare political youth organization *PINK!* noted that “good technology plus bad policy equals bad outcomes [...] We don’t even need this technology to solve many of the problems we currently face”. In other words, from this broader societal and political perspective, innovation may be at odds with the value of sustainability.

As becomes clear from their Principles for Oversight report, civil society organizations have also worries about the consequences of intellectual property in SynBio: “corporations have already applied for extremely broadly worded patents on synthetic biology techniques. If granted, they could give a small number of companies virtual de facto monopoly control over entire economic sectors, affecting the rights of small producers, patients [...] and the public at large” (FOE, CTA & ETC group 2012). Such concerns were shared in the Meeting of Young Minds debate by the Young Greens Party DWARS, who wondered “how one could justify the commercial patenting of life for a badly needed therapy as fair and ethically acceptable” (Rerimassie & Stemerding 2012). In this regard, SynBio innovation is not valued in terms of (market) freedoms, but rather in terms of *justice, solidarity* and *equality*. Indeed, the value of equality is also held in high esteem by those in the SynBio community who favour openness and free sharing of knowledge in the field.

Risk, values and lay morality

A main issue in the SynBio risk discourse is the protection of human health and the environment. Minimizing biosafety and biosecurity risks is seen as a vital condition for a sustainable and safe development of SynBio, a condition that indeed can be claimed as a *citizens’ right*. Another issue, however, is the risk of inaction, that is, the ethics of not developing SynBio and thus foregoing its potential contribution to *sustainability* as a strongly supported value in European society. This raises the question of how potential risks and potential benefits should be weighed against each other.

We have seen that on this point civil society organizations emphasize a strict principle of precaution. This firm precautionary stance is first of all motivated by fear for inadvertent and unknown health or environmental risks. Another important motivation is fear for new forms of exploitation, resulting from an industrial shift to bio-mass derived feed stocks that will benefit the global north while placing further pressure on land and water resources that are crucial for communities in the global south (FOE, CTA & ETC group 2012). Thus, from this critical and global point of view, the SynBio risk discourse also involves values of *justice, solidarity and equality*.

The question of the risk/benefit trade off was also raised in the Meeting of Young Minds debate. Interestingly, DWARS – the political youth organization of the Dutch Green left-wing party that traditionally is very sceptical towards biotechnology – was not opposed to SynBio, provided that regulations and limitations are in place: “while synthetic biology offers opportunities for society, there are also risks involved. DWARS believes that the possible risks should not preclude the potential benefits” (Rerimassie & Stemerding 2012). In other words, SynBio is primarily valued in terms of citizens’ rights that should ensure its safe development for the benefit of society. This attitude we also find in the two UK public dialogue initiatives. Participants perceived SynBio as a double-edged sword, both exciting and scary. Accordingly, in their view, its development should not be stopped, but appropriate safeguards are needed to cope with possible misuse (Battachary et al. 2010; RAE 2009). The available Eurobarometer data contain a similar, yet ambivalent message: on average 39% of the respondents approve of SynBio, while 38% do not approve. Among the respondents that approve only 3% “fully approve and do not think special laws are necessary” and 36% approve as long as SynBio is regulated by strict laws (Eurobarometer Biotechnology 2010).⁷

However, UK dialogue participants were especially wary about the possible uncontrolled release of synthetic organisms into the environment and their ability to evolve and change (Battachary et al. 2010). In the RAE public dialogue meetings there was a clear concern that accidental release would be “large, widespread and significant” given the potential industrial scale of SynBio production (RAE 2009). In neither of these dialogues special SynBio safety mechanisms, such as the use of terminator genes, were seen as sufficient to put these concerns to rest (Battachary et al. 2010; RAE 2009). In the Meeting of Young Minds debate we found a similar strong precautionary attitude on this point. As the Young Greens from DWARS pointed out: “we are extremely reluctant about releasing SynBio products into nature, because it might do a lot of damage that we can’t predict” (Rerimassie & Stemerding 2012).

In the UK public dialogue participants also put forward a more fundamental concern that “scientists should afford dignity, responsibility, respect and attention when intervening in the natural world” (Battachary et al. 2010). During the Meeting of Young Minds debate this concern was most clearly expressed by the Christian Democratic Youth Party: “we see ourselves as stewards of God’s creation with the responsibility to preserve nature for future generations [...] and also from a Darwinian perspective we have to deal with a delicate and precarious equilibrium that has been created in billions of years and that is easily to disrupt”. This concern may also take the form of unease about

⁷ When looking at the three EU GEST countries, we see interesting differences. Germany is most sceptical towards SynBio: only 29% approve, while 52% disapprove. Also in the Netherlands, the majority disapproves, although not as strongly as in Germany: 39% approve, while 44% disapprove. In the UK, however, a majority of respondents is in favour of SynBio: 45% indicating approval to 35% disapproval (Eurobarometer Biotechnology 2010).

the aim of SynBio engineers for total control, as again expressed by the Christian Democratic Youth Party: "Some biologists see it as improving nature. We feel this is not a desirable development" (Rerimassie & Stemerding 2012). Indeed, such concerns about the intrinsic value or *dignity* of nature are more wide-spread, as becomes clear from the European public's troublesome relationship with biotechnology. From the Eurobarometer survey data on GM foods we can see that a high proportion of 70% agrees that GM food is fundamentally unnatural and 61% agrees that GM food makes one feel uneasy (Eurobarometer 2010).

Power& control, values and lay morality

In the power & control discourse we find two approaches towards the governance of SynBio. One approach emphasizes the need for a culture of responsibility, mainly based on professional self-governance. The other approach emphasizes the need for governmental oversight, based on the right of the public to stop or limit technological developments. According to the perspective of 'appropriate risk governance' these approaches should be seen as complementary rather than mutually exclusive. Nevertheless, we have identified in the SynBio power & control discourse conflicts between these two approaches which highlight a tension between the value of market *freedoms* as a basis for innovation and the value of protection as an important *citizen's right*.

This tension was also evident in the Meeting of Young Minds debate. Whereas Young Democrats, Socialists and Greens advocated scientific freedom, the Christian and animal welfare political youth organizations agreed on the opinion that "you should not give a blank check to scientists [...] As a politician, you have the responsibility to control things" (Rerimassie & Stemerding 2012). From the Eurobarometer survey it becomes clear that there is strong public support for this latter opinion. Almost four out of five EU citizens are firmly convinced that SynBio should be tightly regulated by government, while only 11% of Europeans think that SynBio should be allowed to operate freely in the market place (Eurobarometer Biotechnology 2010).

In addition to this tension between market freedoms and citizens' rights, we have identified in the three SynBio discourses tensions with other values as well. While the values of freedoms, citizens' rights and sustainability are dominant in the opinions of actors from science, industry and government, other values like justice, solidarity, equality and dignity are more prominent in the opinions of civil society organizations and in public expressions of lay morality. The question how to deal with this range of values, and conflicts between them, has therefore been defined by organizations like the IRGC as a crucial challenge for the appropriate governance of SynBio. One response to this challenge are repeated pleas for more participatory forms of governance to include a wide range of stakeholders and publics in dialogues and policy making about SynBio. Another response are activities supporting the governance of SynBio in the form of *reflective ethics*, including activities of public ethics advisory bodies and scholarly activities in the field of ethical, legal and social impact (ELSI) studies.

European reflective ethics

Like the risk discourse, ethical reflection has also attended SynBio from its early beginnings (Stemerding & van Est 2013). For example, in 1999, soon after biotech pioneer Craig Venter announced his quest to create a minimal genome, a group of renowned US ethicists examined the "Ethical considerations of synthesising a minimal genome" (Cho et al. 1999). An important factor which stimulated early reflections on the ethical, legal and social implications of SynBio is the

institutionalization in the 1980's and 90's of TA, public bioethics and ELSI research. In this context, ELSI research also became part of the early and current EU funding initiatives in the field of SynBio. Moreover, in 2008, the European Commission asked one of its main ethics advisory bodies, the European Group on Ethics in Science and New Technology, to issue an *Opinion* on “the ethical, legal and social issues that may derive from synthetic biology” (EGE 2009). In this section we will focus on the EGE report as an outstanding example of European *reflective ethics* and also shortly discuss the SYNTH-ETHICS project as one of the EU funded SynBio ELSI research programmes. What is the role of reflective ethics in mapping the issues and shaping the agenda of the emerging and on-going SynBio discourses in society? How does it contribute through these activities to the appropriate governance of SynBio?⁸

Ethics of synthetic biology

In its report on Ethics of synthetic biology, the EGE first of all discusses the main EU and international legal and policy frameworks that are relevant for the governance of the ethical implications of SynBio (EGE 2009). This discussion includes EU regulations and relevant global provisions with regard to biosafety, biosecurity, intellectual property and the potential applications of SynBio, and also the international framework on *ethics and human rights*. On the basis of this international human rights framework the EGE articulates the main values that should guide the ethics of SynBio, including: human dignity, autonomy and responsibility, freedom, equality, solidarity, justice and sustainability.

Starting from this value based legal and policy frame of reference, the EGE addresses a variety of ethical issues in the field of SynBio, whereby it distinguishes between *conceptual* and *specific* ethical issues. Questions concerning the difference between life and non-life, or between the natural and the artificial, are considered as conceptual ethical issues. Such issues relate to questions about the “intrinsic” versus the “instrumental” value that we want to assign to synthetically modified forms of life. Specific ethical issues concern potential applications of SynBio “particularly, but not exclusively from the viewpoint of biosafety and biosecurity”. Intellectual property is also discussed by the EGE as a special and important ethical issue.

Although the EGE discussions in many respects cover the contents of the three SynBio discourses, there is an important difference in approach. The SynBio discourses are primarily issue oriented and the values that inform these issues remain largely implicit. In the EGE approach, values are the explicit starting point for ethical reflection, opening up particular issues that in the SynBio discourses are only marginally addressed. A clear example is the discussion of conceptual ethical issues in which the EGE explicitly reflects on concerns about dignity, responsibility and respect resonating in the SynBio risk discourse. The EGE also focuses the attention on the key role of the precautionary principle in EU policy design and its specific ethical significance in discussions about biosafety. Thereby it qualifies the strict interpretation of the precautionary principle: it does not require refraining from action, but offers a “dynamic tool [...] to verify that the conditions for the acceptability of a given innovation are fulfilled”. The EGE further highlights the value of justice as key to the ethics of SynBio. It specifically refers to the “global justice” discourse, including issues of technology divide and common heritage, and the question of “inter-generational justice”, with implications for preserving the environment and natural resources for future generations. These different considerations finally translate in particular recommendations which underline the need for

⁸ In the context of GEST it is interesting to note that the EGE clearly sees its role to act as a mechanism between social interests (and values?) and the executive and legislative authorities.

funding of interdisciplinary research on questions concerning views towards life, call the Commission to facilitate a standardized approach to biosafety, and urge for specific actions to avoid new gaps between EU and developing and emerging countries.

Playing God?

An example of EU funded interdisciplinary research on views towards life is the 7th framework project SYNTH-ETHICS.⁹ The project offers a comprehensive analysis of ethical and philosophical issues raised by SynBio. One of the issues addressed in the project is a concern provoked by the aim for total control of life and nature, phrased as *playing God*. It is noted that, while the accusation of playing God is probably as old as technology itself, the issue should not be taken lightly, especially since the media have been using the phrase as a powerful buzzword. However, phrased in religious and philosophical terms, the notion of playing God allows different interpretations: “an obvious interpretation is that the creation of life is God’s prerogative and infringing upon His privilege is to be rejected”. But it can also be argued that Christianity actually has a positive stance towards human intervention in nature, that is: “the Christian vision of creation makes a positive judgment on the acceptability of human intervention in nature, which also includes other living beings [...] In effect, nature is not a sacred or divine reality that man must leave alone. Rather, it is a gift offered by the Creator to the human community, entrusted to the intelligence and moral responsibility of men and women” (Link 2009). Thus, from a reflective ethics point of view, there is the opportunity and need to further enrich the debate by a greater variety of views on the ways in which man relates to life and nature.

Conclusion

In the foregoing we have mapped three SynBio discourses and have shown how these discourses are shaped by values and lay morality expressing established value systems in European society. We have summarized the result of our analysis in the discourse/values table below.

		Innovation	Risk	Power & Control
M a r k e t P u b l i c G o o d P r o t e c t i o n	Freedoms	Competitiveness Intellectual property		Culture of responsibility Self-governance Monopolization
	Sustainability	Smart/sustainable growth Social benefits	Risk of inaction	
	Justice	Monopolization	Exploitation	
	Solidarity	Disadvantaging populations	Depletion of resources	
	Equality	Openness Sharing	Increasing inequalities	Incorporation of the public
	Dignity		Unnaturalness Unease about total control	
	Citizens’ Rights	Social responsibility	Minimizing risks Precaution	Governmental oversight Right of the public

On the basis of this table we can distinguish three different perspectives in terms of which we can understand the three different SynBio discourses and tensions between them. Firstly, we can understand these discourses from an *actor perspective*, focusing on the issues that are debated in these discourses. Secondly, we can understand these discourses from a *reflective perspective*,

⁹ <http://www.synthethics.eu>.

focusing on the values that are expressed in these debates. Thirdly, we can understand these discourses from a *governance perspective*, focusing on three central aims for science and technology policy making: market innovation, the public good and protection of individual rights. This governance perspective raises interesting questions for a comparative analysis of SynBio discourses in the three global regions of Europe, China and India. How are these three central aims for S&T policy making prioritized or balanced in the three regions? How to understand this prioritization and balancing in the context of the cultural, socio-economic and political history and current situation in the three regions? To what extent and on what grounds can we define best practices in this respect?

References

- Anderson et al. (2012). 'Engineering and ethical perspectives in synthetic biology'. In: *EMBO Reports* 13 (7), pp. 584-590.
- Ball, P. 'Synthetic biology: Starting from scratch'. In: *Nature*, 431, no. 7009, pp. 624-626.
- Battachary, D. et al. (2010). *Synthetic biology dialogue*. Swindon: Biotechnology and Biological Sciences Research Council.
- Campos, L. (2009). 'That was the synthetic biology that was'. In: Schmidt, M. et al. (Eds.). *Synthetic biology. The technoscience and its societal consequences*. New York and Heidelberg: Springer.
- Caruso, D. (2008). *Synthetic biology. An overview and recommendations for anticipating and addressing emerging risks*. Washington: Center for American Progress.
- Cho, M. et al. (1999). 'Ethical considerations of synthesising a minimal genome'. In: *Science* 286, no. 5447, pp. 2087-2090.
- EASAC. (2010). *Realising European potential in synthetic biology: scientific opportunities and good governance*. Halle: German Academy of Sciences Leopoldina.
- EPTA (2011). *Synthetic Biology. Briefing note no. 1*. EPTA.
- ETC Group (2007). *Extreme Genetic Engineering. An Introduction to Synthetic Biology*. Ottawa: ETC Group.
- European Commission. (2010). *Science and Technology. Special Eurobarometer 340/Wave 73.1*. Brussels: European Commission.
- European Group on Ethics. (2009). *Ethics of Synthetic Biology. Opinion no. 25*. Brussels: European Commission.
- Friends of the Earth, CTA & ETC Group. (2012). *The Principles for the Oversight of Synthetic Biology*. Washington: Friends of the Earth.
- Gaissner, S. et al. (2009). 'Making the most of synthetic biology. Strategies for synthetic biology development in Europe'. In: *EMBO Reports*, 10, Suppl 1: S5-8.
- Gaissner, S. & T. Reiss (2009). 'Shaping the science-industry-policy interface in synthetic biology'. In: *Systems and Synthetic Biology*, 3 (1-4), pp.109-14.
- Gibson, D. et al. (2010). 'Creation of a Bacterial Cell Controlled by a Chemically Synthesized Genome'. In: *Science* 329, no. 5987, pp. 52-56.
- Health Council of the Netherlands, Advisory Council on Health Research, and Royal Netherlands Academy of Arts and Sciences. (2009). *Synthetic biology: creating opportunities*. The Hague: Health Council of the Netherlands.

- IRGC (2010). *Guidelines for the appropriate risk governance of synthetic biology*. Geneva: International Risk Governance Council.
- Link, H. (2010). 'In-Depth analysis of outstanding philosophical issues'. In: *SYNTH-ETHICS. Report WP1. Identification of ethical issues and analysis of public discourse*.
- Marlière, P. (2009). 'The farther, the safer: a manifesto for securely navigating synthetic species away from the old living world'. In: *Systems and Synthetic Biology*, 2 (1-2), pp. 77-84.
- NEST High-Level Expert Group. (2005). *Synthetic Biology. Applying Engineering to Biology*. Luxembourg: Office for Official Publications of the European Communities.
- Netherlands Commission on Genetic Modification. (2008). *Biological machines? Anticipating developments in synthetic biology. COGEM Report CGM/080925-01*. Bilthoven: Netherlands Commission on Genetic Modification.
- OECD & Royal Society. (2010). *Symposium on opportunities and challenges in the emerging field of synthetic biology*. OECD & Royal Society.
- Pei, L. et al. (2011). 'Synthetic biology in the view of European public funding organisations'. *Public Understanding of Science*, 1, pp. 1–14.
- Rerimassie, V. & D. Stemerding. (2012). *Politiek over leven. In debat over synthetische biologie*. The Hague: Rathenau Instituut.
- Roco, M. (2008). 'Possibilities for global governance of emerging technologies'. *Journal Nanoparticle Research*, 10, pp. 11-29.
- Schmidt, M. et al. (2008). 'SYNBIOSAFE e-conference: online community discussion on the societal aspects of synthetic biology'. *Systems and Synthetic Biology*, 2(1-2): pp.7-17
- Schmidt, M. (2009). 'Do I understand what I can create? Biosafety issues in SB'. In: Schmidt, M. et al. (Eds.). *Synthetic biology: The technoscience and its societal consequences*. New York and Heidelberg: Springer.
- Schmidt, M. (2010). 'Xenobiology: A new form of life as the ultimate biosafety tool'. In: *Bioessays*, 32 (4), pp. 322-331.
- Schroeder, D.(2012). 'European values system governing S&T ethics. An overview.' In: *Global Ethics in Science and Technology. Work Package 1: Ethics state of the art*.
- Stemerding, D. et al. (2009). 'Synthetic biology and the role of civil society organizations: shaping the agenda and arena of the public debate'. In: Schmidt, M. et al. (eds). *Synthetic biology. The technoscience and its societal consequences*. New York and Heidelberg: Springer.
- Stemerding, D. & R. van Est (red) (2013). *Geen debat zonder publiek. Het opkomende debat over synthetische biologie ontleed*. Den Haag: Rathenau Instituut.

Tait, J. (2009). 'Governing synthetic biology: processes and outcomes'. In: Schmidt, M. et al. (eds). *Synthetic biology. The technoscience and its societal consequences*. New York and Heidelberg: Springer.

TESSY (2008). *Documentation of TESSY Stakeholder Workshop Brussels, 10 June 2008. Opportunities for Stakeholders. TESSY Deliverable D3.2.*

Torgersen, H. (2009). 'Synthetic biology in society: learning from past experience?'. *Systems and Synthetic Biology*, 3 (1-4), pp. 9-17.

Torgersen, H. et al. (2010). 'Engineering of living artefacts: synthetic biology'. In: Van Est, R. et al. (red.). *Making Perfect Life. Bioengineering (in) the 21st Century. Monitoring Report Phase II*. Brussels: STOA.

Van Maanen, G., 'Synthetische biologie split ministers' In: *Bionieuws* 16 April 2008.

Wohlsen, M. (2011). *Biopunk. DIY scientists hack the software of life*. New York: Current.

Zhang, J. et al. (2011). *The transnational governance of synthetic biology. Scientific uncertainty, cross-borderness and the 'art' of governance*. London: BIOS, London School of Economics and Political Science.