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COMMENTARY

# SYNBIOSAFE e-conference: online community discussion on the societal aspects of synthetic biology

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**Abstract** As part of the SYNBIOSAFE project, we carried out an open electronic conference (e-conference), with the aim to stimulate an open debate on the societal issues of synthetic biology in a proactive way. The e-conference attracted 124 registered participants from 23 different countries and different professional backgrounds, who wrote 182 contributions in six different categories: (I) Ethics; (II) Safety; (III) Security; (IV) IPR; (V) Governance and regulation; (VI) and Public perception. In this paper we discuss the main arguments brought up during the e-conference and provide our conclusions about how the community thinks, and thinks differently on the societal impact of synthetic biology. Finally we conclude that there is a chance for an open discourse on the societal issues of synthetic biology happening, and that the rules to govern such a discourse might be set up much easier and be respected more readily than many would suggest.

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## Aims and scope of the SYNBIOSAFE e-conference

Synthetic Biology (SB) is becoming one of the most dynamic new fields of biology, with the potential to revolutionize the way we do biotechnology today. By applying the toolbox of engineering disciplines to biology, a whole set of potential applications are made possible ranging very widely across scientific and engineering disciplines. Some of the potential benefits of SB, such as the development of low-cost drugs or the production of chemicals and energy by engineered bacteria are projected to be enormous. There are, however, also potential and perceived risks related to deliberate or accidental damage. In order to ensure a vital and successful development of this new scientific field and in addition to addressing its potential benefits, it is absolutely necessary to gather information about risks and to devise biosafety strategies to minimize them. Also, the ethical issues of SB are just beginning to be explored, with few ethicists specifically focusing on the area of SB (de Vriend 2006; van Est et al. 2007). While a few undertakings on safety and ethics have recently started in the US, our project SYNBIOSAFE is the first initiative in Europe which focuses particularly on the safety, security, and ethical concerns and which tries to facilitate a socially acceptable development of SB. We have co-organized the safety/security and ethical sessions at the SB 3.0 in Zurich last June, and since then have carried out a survey among leading European SB practitioners regarding their viewpoints on safety, security and ethical issues (e.g., Kelle 2007). We then wanted to discuss the selected issues with a wider group of experts and interested stakeholders. Thus we carried out an open online conference—or e-conference—on the internet. The aim of this open e-conference was to further stimulate the debate on these issues in a proactive way, at a relatively early stage. The discussions and consultations during the e-conference were a first contribution to stimulate a wider debate on the societal impact of SB.

## Methodology

The preparation of the e-conference included four major steps:

- The preparation of a background paper (Schmidt et al. 2008)
- The elaboration of a list of persons to be invited to join the e-conference
- The technical set-up of the e-conference and different forums
- The sending out of invitations and guidelines

The selection of invited people was primarily based on participant lists from major SB related conferences, notably SB2.0 (Berkeley, May 2006), SB3.0 (Zurich, 06/2007), the ESF conference on SB (ECSB) (Barcelona, 11/2007) the joint Visionary Seminar of Leuven. Inc and IMEC (Leuven, 11/2007) and the list of 38 NGOs that signed the petition letter against the SB 2.0 self-governance declaration. Moreover, SYNBIOSAFE project members as well as the Advisory Board members were encouraged to provide additional contacts of scientists, non-scientists, relevant NGOs, and their representatives. For the technical set up of the e-conference, specific provisions were taken into consideration in order to avoid any form of misuse. Comprehensive instructions were given to participants through specific guidelines on how to participate in the conference. The e-conference finally took place between May 5 and June 9, 2008. Over this period, weekly downloadable summaries gave an overview on the development of the e-conference. In the final week, an additional forum was created in view of encouraging the participants to express and discuss recommendations related to the questions and issues raised during the e-conference.

## Participation and statistics of the e-conference

We directly invited over 1,000 people (mainly scientists, but also representatives from NGOs, funding agencies, industry, and other stakeholders) to our e-conference.

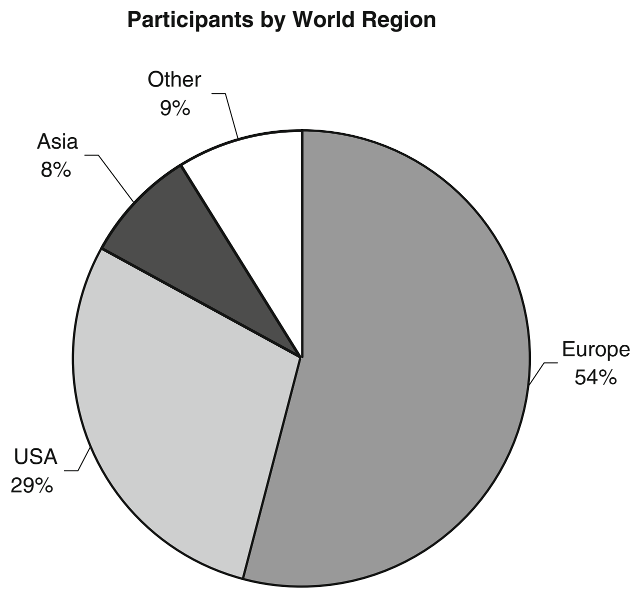


**Fig. 1** Distribution of registered participants by world regions, the total number of participants was 124. Asian participants came from China, India, Japan, and Georgia. The category "other" includes participants from Australia, Argentina, Brazil, Canada, and New Zealand

In addition the e-conference was announced on several websites.[1] Finally we had 124 registered participants from 23 different countries (see Figs. 1, 2) and from different professional backgrounds (Fig. 3). In total 36 participants actively posted one or more contributions to the online forum, representing about 30% of the total number registered. Contributions were distributed to the different fora as shown in Figs. 4 and 5. The Forum I on Ethical aspects received the most attention from participants. Only three postings were made regarding recommendations. This may have been due to the fact that this forum had only been subsequently added during the final week of the e-conference.

The original contributions can be seen at www.synbiosafe.eu/forum and are also available in one compiled document (SYNBIOSAFE 2008).

## Summary of contributions

We will now discuss the contributions made by the active e-conference participants in the six main categories: (I) Ethics; (II) Biosafety; (III) Biosecurity; (IV) Intellectual property rights; (V) Regulation and governance; (VI) Public perception, communication and the media.

[1] Example http://syntheticbiology.org, or in the English and German Wikipedia entries on SB. Also other people posted the note on their respective websites.

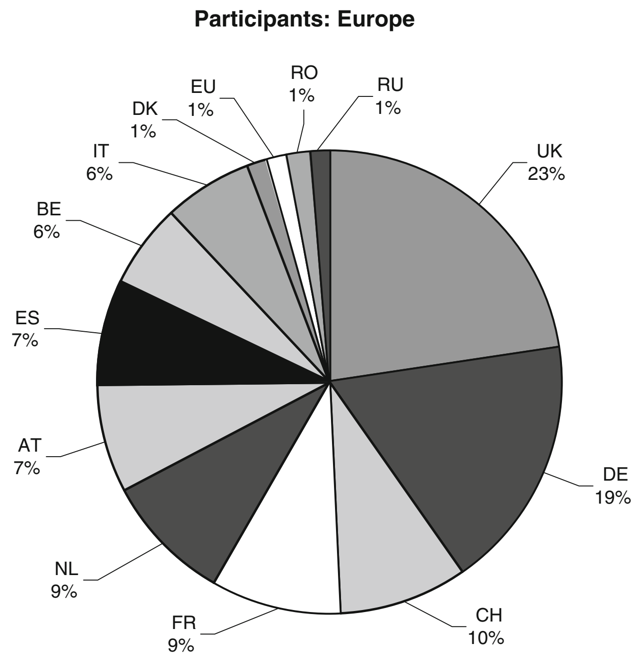


**Fig. 2** Most European participants were from the United Kingdom, followed by Germany, Switzerland, France, and the Netherlands. Only one participant came from Eastern Europe (Romania), one from Russia, and one from the European Commission (EU). All values are rounded ($n = 67$)

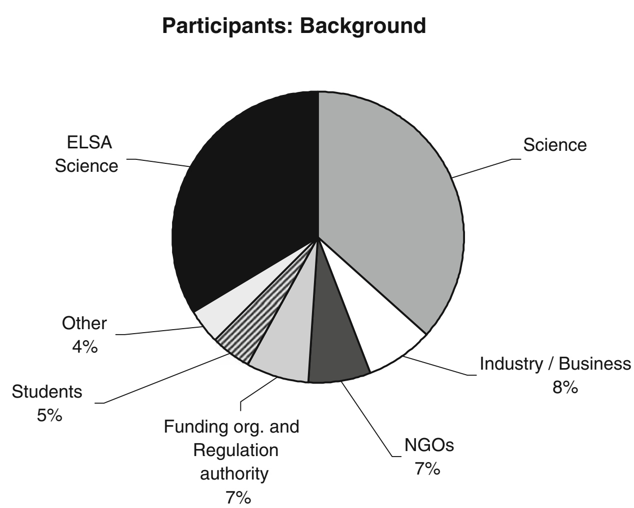


**Fig. 3** About two-thirds of the participants were scientists, either scientists working in R&D (science) or scientists working in e.g., ethics, political sciences, safety, security, intellectual property rights, governance (ELSA science). Some participants, however, were from the industry or business, from NGOs, funding organizations and regulatory authorities. The smallest fraction was made up of students and other (film makers, journalists, think tanks, artists)

## Ethics

In this category, we touched upon topics that we expected might give rise to ethical concerns in the field of SB. We did so through eight statements and questions (see

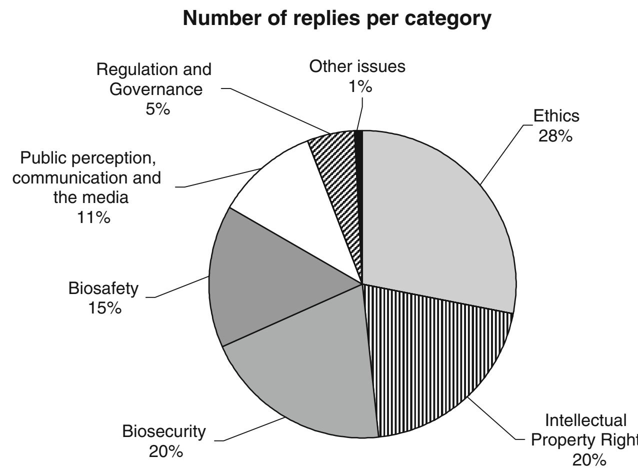


**Fig. 4** According to the number of postings (replies) per category, Ethics received the highest attention, followed by IPR, Biosecurity, and Biosafety ($n = 182$)

background paper) which we felt might trigger debate. Interestingly, the ethics section of the forum was viewed more frequently than the other sections (over 400 views). This indicates that while the safety and security aspects of SB may be most pressing, those interested in the field are also keen to discuss the various ethical and philosophical concerns that may arise.

In one topic, we addressed a central theme within SB: the idea of 'creating life' from scratch, in a way only nature has done so far ('playing God') as well as the often powerful yet difficult to pin-point feeling of uneasiness that surrounds the emergence of such a technology, a feeling that may either reflect our prejudices or be an indicator of deeper ethical problems. This topic received much interest within the forum with contributors taking the opportunity of the platform to sound out their own intuitions on this issue.

As expected, participants highlighted the importance of defining what 'life' is: *"Is it just organisms that are on a biochemical level related to the biochemistry of natural living organisms on earth?…Many of the things we call 'synthetic life forms'—such as Mycoplasma laboratorium—are actually almost 100% based on natural species—the reason we call them synthetic life is more the process of how we instantiate them"*. This concern precisely pin points the difficult conceptual questions surrounding SB, which are sometimes underestimated in their effect on sharing the normative debate around it.

Another participant felt that 'the concept of 'life' as a vague mysterious property that is magically bestowed upon organisms is misleading: *"We are currently making good progress in understanding the mechanics of microorganisms…It becomes obvious that such microorganisms are 'just' machines, and that the creation of new such*

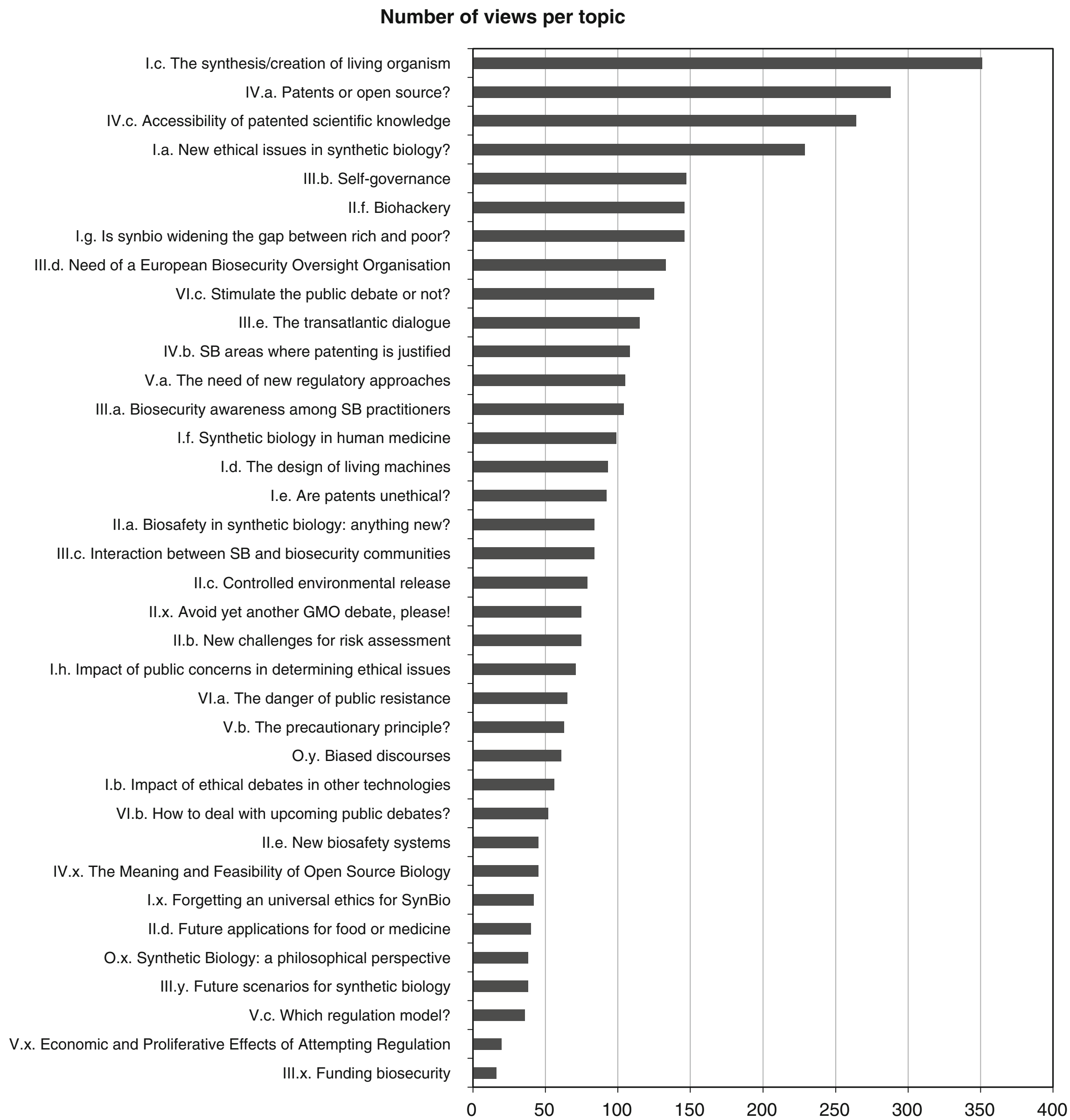


**Fig. 5** According to the number of views per topic, four topics from two categories (ethics and IPR) were most popular, followed by four topics from the categories biosecurity and biosafety

*machines shouldn't be considered differently"*. Both participants here illustrate the complexity involved in establishing a conceptual base for the ethical framework, given the existing pluralism in attitude and approach towards living organisms.

According to a participant, the existing debate on the ethics of sciences applies well to SB and as such, there are no new ethical issues. Here, as it was noted, the discussion essentially revolved around the 'ethics of consequence' (something is good if it produces good consequences, in this case good applications), rather than an 'ethics of principles'. However, according to one observer, even applying the ethics of consequences is not necessarily objective: *"the debate on genetically engineered crops has demonstrated how the appreciation of consequences can differ. What is a good and what is a bad consequence is always related to a certain situation of reference… it is very important to be aware of this societal context"*. However, most concerns related to products and applications and many felt that rather than concentrating on the act of creating new life or living organisms, we should concentrate on the attributes of these new organisms. While creating 'more-of-the-same' could be considered ethically unproblematic, certain (formerly absent) characteristics or uses of synthetic organisms may require special scrutiny. Taking this point further, some suggest that as long as new characteristics do not pose new safety concerns, they should not be considered ethically problematic either.

Participants also tackled the suggestion that a negative intuition or feeling of uneasiness may work as an indicator of ethical concerns regarding a technology that shakes some of our deep-rooted beliefs regarding life and living organisms as created by nature. One such person, having closely witnessed the deliberation of a policy-making body, warned against the tendency to take moral intuitions too seriously, illustrating how legislation on such topics may be difficult to establish unless backed by other substantive arguments: *"An argument simply based on discomfort is very unlikely to find much support. Nor are arguments about intrinsic values…unless they can be tied to some notion of harm"*. This thread was taken further by comparing how the discomfort around SB might be compared to that which arose, and continues to arise around reproductive technologies, which challenge concepts of family and parenthood.

With respect to the idea of 'playing God', it was argued that human activities of all kinds, including science and technology could be considered 'natural'. In other words, playing God need not necessarily be used as a basis for admonition. However, a certain amount of precaution is required: *"We may think that we can accurately predict the consequences of our actions with respect to living organisms—but history tells a different story. Hence a sensible degree of respect for the precautionary principle should remain…Can we pull the plug? Can we stop our project before it spirals out of control? That is an ethical question."*

In a third question, we asked whether SB in human cells and human beings should be allowed, especially in the context of medicine but also for possible non-therapeutic uses. While some earlier contributors to the forum warned against letting our imaginations run wild towards GATTACA-like scenarios, much of the discussion did in fact veer towards the topic of enhancement and transhumanism. Here, some effort was made to distinguish between transhumanist and eugenic movements: whereas the idea of 'superhumans' is interesting, we must distinguish between 'eugenical' conceptions and the ideas of personal self-transformation, which were the original roots of transhumanism. However, this topic dried out at an early stage, principally because it was felt that SB may not be at a stage where such scenarios are likely to be realized. One participant felt that while it is not too early to start such a discussion, more importance should be given to discussing what we want to achieve with SB and how the research should be carried out.

On the question of whether SB might widen the gap between the rich and the poor, two participants agreed that because the costs of proliferation and scale-up are marginal for SB products, SB may in fact reduce rather than widen the gap between rich and poor: *"Poor, developing countries have many disadvantages, such as a lack of educated scientists, insufficient infrastructure etc., so that it will be difficult for them to participate in the very complex (and thus expensive) process of developing new SB products. However, these disadvantages apply to every technical field and are not specific to SB. Then, as opposed to virtually all other technical fields, the 'free' (to a first approximation) scale-up of living systems is an important advantage that could be leveraged by developing countries"*.

The final point which received some attention from participants to the forum was one raised by a participant. He suggested that SB was offering us a context in which there were no coded answers from classical ethical systems. Assuming that we need a new ethical framework for SB, his suggestion was that there should be a (transitory) ethics of emotions to address this new human creationist environment. As an answer, another participant felt that such an approach would closely match that of a philosophy of extropy, which *"is based on the values of openness, rational thinking, self-direction and the proactionary principle"*. The main concern regarding this approach would be that such an approach will have to come from within the community but it was felt that such a development will not occur unless there is outside pressure: *"At the same time there is the problem to consider…that good will and freedom of beliefs will bring universal agreement. And this is the typical mistake. People usually act in a certain way when there are forced (by external or internal pressures) to it."*

Summarizing the input in the ethics category, the most popular topic was the creation of living organisms. While some participants felt that the creation of synthetic organisms presented no real ethical concerns, others argued that this presented at least some new philosophical questions with regards to the definition of life. Whether SB presented new ethical question was also subject to divergent opinions. While some felt that the new technology presented no new ethical concerns as long as the risks were contained, others felt that the creation of new life required the creation of a new ethics, to answer questions that may arise with the development of new products. Concerns where directed at the products of SB rather than on the technology itself. Application on human cells gave rise to a discussion on enhancement and transhumanism. Finally, regarding whether we should worry about a potential "SB-divide", similar to an IT-divide, a gene-divide or a nano-divide, it was felt that beyond the initial infrastructural difficulties, the production of synthetic organisms may become a viable technology for developing countries.

## Biosafety

To begin with, we asked whether SB raised new biosafety questions at all. This is directly linked to the definition of

SB and to its perceived difference from genetic engineering in a traditional sense. The question was raised whether there is a difference between GMOs and synthetic organisms, and where to draw the boundary.

A participant understood the reassembly of existing genetic elements into a single life form (genetic circuits, biobricks) and the quest for a minimal organism to be sophisticated continuations of genetic engineering. This implies that the biosafety issues would only differ quantitatively and not qualitatively. Participants, however, concluded that if the "de-skilling" agenda (in other words to make it easier to construct new life forms) would prove successful and more people would be able to design new living systems, a qualitatively new challenge would arise. Also the construction of life forms based on alternative biological systems (e.g., chemically different nucleotides) would raise qualitatively different challenges.

We further asked whether the current biosafety framework may be considered appropriate for the environmental release of "synthetic" organisms. Recent discussions on the Cartagena Protocol on Biosafety (CBD 2008) revealed that developments in SB could lead to significant gaps despite the risk assessment framework presently in place for GMOs. Currently, all risk assessments of living modified organisms are conducted on a case-by-case basis as the impacts depend upon the trait inserted, the recipient organism and the environment into which it is released. One of the differences between genetic engineering and SB is that instead of single parts, whole systems can be transferred, using hundreds or thousands of traits from different donor organisms (multiple hybrids). Emergent effects in the creation of synthetic genetic circuits could cause problems in the design process and create new uncertainties, so it is a relevant question whether the established risk assessment practice is capable of dealing with multiple hybrids. Also, the use of biological systems made of alternative biochemical structures (enlarged genetic alphabet) can probably not be assessed by current risk research practices.[2]

Few responses were obtained regarding the use of SB in order to improve current biosafety systems. By making systems more artificial (orthogonal), they may be rendered unable to interact with natural systems. One participant mentioned that such work had been carried out at least to some extent, and that it would be a feasible option.

The topic of "biohackery" elicited a more intense discussion, especially on how realistic a biohacker scenario was, and how biohackers would affect biosafety considerations (see Schmidt 2008). Referring to the DIY Biology google group,[3] a small but enthusiastic and growing community of biohackers does seem to exist (at least in the US). In terms of biosafety some participants argued for individual certification and controlled access to key reagents or equipment in order to reduce the safety risks and to maintain control over the community. Others rejected any kind of oversight by a few "privileged" and argued for full democratization of biotechnology. Comparable to a Wikipedia approach, they proposed to give every citizen the possibility to design and fabricate biological systems without being controlled by any kind of authority. Other participants warned that such a total laissez-fair approach to SB (everybody is allowed to design any kind of organism) could lead to unprecedented risks and biological catastrophes. The answer to this was that a catastrophe could be avoided if everybody would have the tools to inhibit it. This line of argumentation supported the development of a smart, empowered community capable of responding quickly to problems, but also voiced the fear that—with open access—we could *"mindlessly screw up the unity of life on earth"*.

The difference between the US and Europe over fears regarding biosecurity (mainly in US) and biosafety (mainly in Europe) got special attention. It was felt that we should avoid indulging in yet another GMO debate in Europe, which might arise from false alarms and too provocative a language (implying terms such as "engineering life" or "artificial cells"). In the same vein, scientists should avoid "over-hyping" benefits and risks and try to keep the debate and public exposure to the technology within reasonable terms.

Discussing the lessons learned from the GMO debate, e-conference participants found it necessary to avoid the dominance of trans-national companies and allowing for an open source biology movement. Formerly, companies, authorities and the scientific community had not taken into account the social and moral concerns of NGOs and consumers. What was needed in order to avoid mistakes of the past was an open dialog between all involved stakeholders, substantial public funding for the field instead of the dominance of a few companies, a clear analysis as to which new safety regulations would be needed (and which to be avoided) and the acceptance that there are other points of view than those held by western scientists.

Taken together, the main issues seemed to be firstly, whether SB as compared to genetic engineering poses qualitatively new problems or whether there is a quantitative extension of known issues only. Participants seemed to hold different opinions as to which lessons can be drawn from the experiences with genetic engineering, regarding biosafety issues as well as public fears and hopes. It was suggested that notable gaps exist in the knowledge base for

[2] Among the few applications of SB, a genetic alphabet consisting of alternative bases is used in diagnostic systems for detecting viral infections.

[3] See: http://groups.google.com/group/diybio/topics.

an appropriate risk assessment of SB. Secondly, how to deal with societal developments resulting from the diffusion of knowledge such as biohackery triggered some debate. Proponents of stricter regulation met participants who argued for a community based approach to prevent unintended negative consequences.

## Biosecurity awareness

A study conducted as part of the SYNBIOSAFE project in 2007 sought to establish the level of biosecurity awareness among 20 leading European SB practitioners (Kelle 2007). The interviews conducted to this end focused on several of the milestones and key developments in the biosecurity discourse as it had evolved over the past few years mostly in the US. This survey showed an overall low level of awareness of this biosecurity discourse, in particular with respect to a report by the US National Academy of Sciences (NAS), in which SB had been explicitly identified as one area of concern for future bioweapons developments. The NAS report expressed concern that "DNA synthesis technology could allow for the efficient, rapid synthesis of viral and other pathogen genomes—either for the purposes of vaccine development, or for malevolent purposes or with unwanted consequences." (NRC 2006).

Against this background the biosecurity section of the e-conference sought first to stimulate some discussion about how the level of biosecurity awareness among SB practitioners might be raised. One comment pointed to the fact that there may be varying levels of biosecurity awareness among different parts of the SB community, with awareness being widespread among gene synthesis companies and their industry organizations. The fact that such diverging degrees of awareness should exist—and have been apparent during the above-mentioned interviews with SB practitioners in 2007—does not come as a surprise given the requirement for gene synthesis companies to comply with export control measures agreed among states participating in the so-called Australia Group.[4] There was a general consensus among e-conference participants that education would be key in raising the level of awareness, especially among those entering the field of SB, be it from other disciplines, such as engineering, or with a view to the next generation of SB practitioners by redesigning science and technology curricula from high-school level onwards in order to effect a long-term change in this realm.

Linked to the question of the awareness of biosecurity issues among SB practitioners was the question of the practicability of self-governance mechanisms on the part of the SB community in order to prevent the misuse of this new field of research. While some e-conference participants seemed to worry that technology was moving too fast and was too easily accessible to rely entirely on self-governance mechanisms, others were more optimistic that in case of misuse one might deploy *"just as easily synthetic genes as countermeasures"*. Another participant pointed out that at this point in time self-governance was vital because governments simply had not yet caught up with developments. Furthermore, government regulation would also be useful in promoting SB, as it would provide a safe legal foundation upon which to operate. Others, however, cautioned that care would need to be taken that the SB community would not perceive formulation of regulatory measures as directed against them. Hence SB practitioners' pro-active participation in such regulatory instruments would be essential.

Discussion on the potential to foster the interaction between the SB and biosecurity communities received fewer interventions than other biosecurity aspects. One current proposal put forward by a group of US SB experts aims to establish an on-line clearing-house mechanism where researchers could receive biosecurity advice on potential experiments of concern. While certainly not a one-stop solution to address all areas, an increased interaction between SB practitioners and biosecurity experts would be desirable. An online portal could make a useful contribution towards educating the SB community—assuming researchers will consult it frequently before conducting an experiment or even submitting a grant application.

Concerning a potential European Biosecurity Oversight Organisation (EBOO), there seemed to be a consensus developing initially, according to which effective oversight of biology and protection from a biochemical catastrophe were impossible, and, by implication, that an EBOO would be useless. A later comment, however, pointed out that such an EBOO could be beneficial in a number of ways: it would provide a reassurance to the public that somebody was taking the biosafety and biosecurity implications of SB seriously; it could serve as an umbrella organization harmonizing national efforts to address biosecurity issues, and it could define clear standards of compliance for industry. These comments were reinforced by another participant, who emphasized the positive contribution made by gene synthesis companies through their efforts to institutionalize a comprehensive screening of DNA sequences before orders are being sent out. An EBOO, in this view, would usefully complement a bottom-up approach favored by many for successfully developing SB.

With respect to potential improvements in the transatlantic dialog on biosecurity implications of SB, a reference was made by one participant to the US National Science Advisory Board on Biosecurity (NSABB) in this regard.[5]

[4] See www.australiagroup.net for more information.

[5] See www.biosecurityboard.gov for more information.

Indeed, the NSABB has set up a Working Group on International Collaboration, which in turn has undertaken some activities with a view to discuss biosecurity issues and dual-use research in the life sciences in more general terms. Another e-conference participant pointed out that the two industry associations in the field of SB, the IASB and the ICPS, were likely to move beyond a mere dialog to concrete action, in order to move forward on the screening of DNA sequences by gene synthesis companies.[6] Noteworthy in this context is the biosecurity workshop organized by the IASB at the analytica in Munich, Germany, on 3 April 2008.

Last but certainly not least, attention needs to be drawn to a new subcategory of the biosecurity section of the e-conference. It raised the issue of funding (or rather the lack thereof) for biosecurity related research in the SB field, pointing out that the provision of sufficient funding of biosecurity measures now would have several benefits: one would have to engage a relatively small SB community only; biosecurity solutions could grow along with developments in SB, and; starting work on these issues now would put everybody with an interest in the unhampered development of SB in a stronger position once the public debate on the benefits and potential downsides of SB started in earnest.

Taken together, there is currently a low level of awareness for biosecurity issues among academic SB practitioners in Europe, although gene synthesis companies have launched some promising initiatives. There were different views on how to proceed, in particular over the role of self-governance. Institutional solutions with different structures and competences highlight the different functions regulation may take, from preventing disaster to providing a framework for the safe operation of industry and a reassurance for the public. Adequate biosecurity funding may also lead to a better informed debate on the risks involved in SB.

## Intellectual property rights (IPR)

Synthetic Biology is a young discipline; therefore, it is still unclear how the accessibility of its results and products should be regulated. We opened the discussion on IPR issues with the question whether patents or an open source system, as known from software, would be a more appropriate strategy for SB (Henkel and Maurer 2007; Hope 2008). One respondent pointed out that whether patents were desirable or not depended on the objectives related to them. He thought that in patent commons, where patents were pledged for a pool and others were encouraged to use them for development purposes, patents could be desirable. Another participant agreed that there was no proven argumentation saying open source was always better than patents or vice versa. But in case of the development of standards, which everybody wants to share, he clearly pleaded for open source. He argued that the decision on which of several standards was most widely used was based on an accidental selection. Since patents should not reward an "accident in history", standards should not be patented.

Another participant disagreed, because he thought parts could only be commercialized if they could be protected from competing companies. He noted that a system was required in which businesses could patent parts whereas they remained freely accessible for academic researchers this could be achieved by licenses, which would grant free use of patented parts to academic research and hobbyists.

One discussant conceded that "open source" without patents was a desirable strategy for computer software, but he doubted that it was applicable for biology because the analogy between software and biological technologies was not correct *"DNA is neither physically nor legally the same thing as code and biology is neither physically nor legally the same thing as software."* He argued that the distribution of DNA licenses required the exclusion of others using the DNA, and that this was today only possible via a patent. However, in computer technology it was easier to exclude others from using a source code, because the computer scientist had written it by himself.

To the question in which areas of SB patenting was justified one participant replied that patenting of basic tools could hinder academic research and the development of SB applications especially if patents had broad claims or were overlapping. Another respondent stated that our question implied that there were areas of SB in which patenting was not justified, which he regarded as a questionable assumption. Furthermore, he believed that it did not make sense to discuss patent issues in the isolated context of SB, because SB was not different from other technical areas.

One discussant pointed out that patents did not primarily limit the accessibility of the patented object but that, on the contrary, scientific knowledge could remain accessible thanks to patents because without patents companies would not open their inventions and discoveries to the public.

Taken together, the contributions of the IPR section illustrate the different positions of open access proponents and participants who considered such an approach as not desirable or not feasible. This difference reflects the conflict of interest between academic research and commercial application. Moreover, the e-conference depicts the different perceptions of patents. For some participants patents symbolize a closed strategy, for others they are the prerequisite to make scientific knowledge accessible.

[6] See the webpages of the International Consortium for Polynucleotide Synthesis (ICPS) at http://pgen.us/ICPS.htm and of the Industry Association SB (IASB) at http://www.ia-sb.eu/.

## Regulation

Starting from the question whether there is a need for new regulation, a participant contributed a long excerpt from an upcoming book chapter to discuss the merits and perils of SB regulation. The argument was that attempts at controlling the production and distribution of knowledge, skills, and materials are doomed to fail. Taking the example of illegal drugs regulation, it shows how a black market is created, production is driven to clandestine organizations abroad and control is efficiently prevented. While nuclear proliferation control is achieved via prohibiting access to key materials, with biology raw material is ubiquitous and scientists educated in industrialized countries spread the skills all over the world. Therefore, regulation is neither possible nor sensible and would diminish security. Rather, the strategy should be to ensure that activities in SB are transparent.

Other participants seemed to be reluctant to discuss the issue in general terms; rather, they pointed at various reports on nanotechnology providing examples of how to do: the Royal Society (2004) report asked for involving "a variety of publics" to construct a regulatory framework not the least in order to modulate commercial influence. The US Lemon–Relman report (Relman et al. 2006) called for broad risk awareness, and the NSABB (2007) report proposed oversight over dual-use life-science research including a dialog with other countries in analogy to chemical weapons regulation. The EC (2008) attempted to establish a Code of Conduct towards good governance of nanotechnology incorporating the "seven principles". In addition, as a practical way to involvement, community "hands-on" projects in SB were proposed to enhance the motivation for discussing issues.

Should the precautionary principle be applied, and what might be the outcome? A participant pointed out that most European countries have revised their regulatory frameworks towards separation of science and politics, to transparency and participation. The precautionary principle gets progressively adapted towards more flexibility rather than more regulation. For SB, a mix of technology assessment and regulatory alternatives could provide new ways of decision-making. Another participant considered the precautionary principle to halt technology development and proposed a "proactionary" principle emphasizing the right to innovate as an alternative.

## Perception and media

A crucial question is whether SB will meet public resistance as agricultural biotechnology did. A participant suggested that new technologies do not necessarily trigger adverse reactions and that SB could be as accepted as mobile phones are today. While user benefits of mobile phones have been obvious before risks became apparent, it was argued that at least in Europe, there might be a public bias for skepticism because supporters had downplayed the risks of technological breakthroughs. With new technology, people might fear unknowns as well as exploitation by powerful interests. Since SB has a low profile yet, a contributor thought that protests are less likely. They would be possible, however, if something untoward happens, which then might ensue heavy regulation or lack of funding. The example of artemisinin shows that "unknowns" loose their threat if benefits for humanity can be shown. A participant emphasized the role of fascination seen with the iGEM competition,[7] which may influence perceptions positively. Accordingly, a prerequisite is a rudimentary public understanding of science. Hyperbolic expectations, however, should be tempered in order not to create disappointment.

As the most appropriate way of influencing perceptions, participation rather than attempts at technically steering the debate was proposed. Scientists' role could be to "inject" scientific knowledge as well as examples of applications, such as it had happened with stem cell research. Conceptual and terminological correctness is necessary, in particular regarding terms that might elicit fear such as "artificial life". Also, problems should be defined correctly and not just sold as new.

Whether scientists should engage in a public debate might be a matter of timing and wording. A participant considered relevant messages and the right way of communication a prerequisite. Again, nanotechnology got mentioned as an example that has become positively framed in contrast to agricultural biotechnology. Here, a balance has been achieved between the communication of benefits from daily products and risks without denying the latter, resulting in a positive-neutral image. This was attributed to the involvement of scientists from the very beginning. Accordingly for SB, daily experiences with applications need to be linked to general visions and approaches. Scientists have to back this process with facts, bridging the gap between science and public usage. However, scientists should always gauge the effects of their communication efforts.

A participant proposed to take a contrasting approach from the very beginning by openly involving different publics in a wider debate about what drives science today. Referring to the Demos report (Irwin et al. 2006), it was stressed that scientists have learned from discussing the publics' various understandings as much as lay people have learned from scientists. "The public" consists of many

[7] See http://parts2.mit.edu/wiki/index.php/Main_Page.

different people, and reciprocity rather than getting across the right message is the prerequisite for success.

In conclusion, there is reluctance on the feasibility, and the sensibility, of a special regulation of SB. The example of nanotechnology shows that there are a variety of other approaches better suited to deal with new technology. This could also refer to more traditional interpretations of the precautionary principle. Regarding public perceptions, again the example of nanotechnology demonstrates that it is possible to arrive at a neutral to positive image, provided scientists take a more reflexive and less one-way oriented approach towards the public than with genetic engineering in the past.

## Conclusions

Throughout the e-conference, inherent analogies played an important role. Most prominently, the question was whether SB was to be considered an entirely new development or merely an extension of previous endeavors, for example, in genetic engineering. Consequently, implications both with respect to ethical, safety, and security risk issues appeared in a different light depending on their throwing up entirely new problems or just transferring existing problems to a new level.

Regarding biosafety, there are different opinions on the novelty of risk issues. Although there are established risk assessment protocols, in the light of radically new developments current approaches might turn out to be inadequate. While risk featured prominently also with respect to ethics, it is an error to believe people are interested only in safety and security issues or the consequences (e.g., in terms of justice) of certain applications. Apparently many participants thought that creating new forms of life did not just raise the issue of accidentally washing altered bacteria down the sink. Thus, more fundamental questions may well play a role when debating SB in the future. This does not only refer to the issue of "creating life" but also to certain applications, in particular those that aim at improving human performance by technical means to the amount of arriving at new forms of human beings. Clearly, such aims might fuel a debate that exceeds that over genetic engineering over recent years.

Greater concerns seem to be triggered by the popularization of knowledge supported by parts of the SB community. Again, what is at stake seems to be determined by analogies, in this case the analogy to the proliferation of programming skills giving rise to the sub-culture of hackers (Schmidt 2008). Such biohacking might in fact constitute a serious threat in terms of safety and/or security, although there seem to be different opinions as to the significance of such issues on both sides of the Atlantic. Again, analogies to problems unrelated to SB but more or less visible on the political agenda may play an important role in determining reactions to perceived threats.

Comparing SB to computer science might also have left its mark on the discussion over intellectual property rights. Apart from the question whether there can be drawn analogies between the both of them at all, generic issues of patenting versus open source played a role that may go beyond factual arguing and be rooted in different value systems.

How to deal with real—or perceived—threats? The issue of potential regulation comes easily to mind, but there are obvious limits to its feasibility and sensibility. In an era where top-down regulation gives way to governance involving relevant stakeholders, previous debates about whether or not to go for a strict regulatory approach seem out of place. Nanotechnology provides an example of how to deal with an emerging technology, retaining a neutral or positive public image. The argument that regulation is necessary for reasons of public perceptions may be outdated. Whether it is necessary to prevent harm might be another question.

Therefore, the analogy to past debates on genetic engineering may have its limits. Yet it is this debate that many participants think will be revived with SB. There are clear indications of fear within the scientific community of a conflict under the header of "GMOs revisited", and they struggle for lessons that could have been learned. However, participants do not agree on the most appropriate strategy to avoid such a conflict. Opinions range from "being proactive" to "avoiding hype" or "not drawing too much attention to the field".

As a conclusion from our e-conference we can say that there is a need for genuine discourse that does not exclude more fundamental question of how we think, and think differently, about the moral status of the life forms SB deals with, now and in the future. Reflexivity in such a discourse means that it will be more about finding out how interests and world-views differ, and what to do with such differences, than to figure out the single answer to these questions.

Our e-conference has shown that there is a chance for such a discourse happening, as we have experienced participation beyond expectation both with respect to the number of views and contributions as well as to the variety of backgrounds and arguments. It showed that the rules to govern such a discourse might be set up much easier and be respected more readily than many would suggest. In our opinion, this is a good harbinger of debates on SB to come.

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