The art of trans-boundary governance: the case of synthetic biology

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Abstract Synthetic biology raises few, if any, social concerns that are distinctively new. Similar to many other convergent technologies, synthetic biology's interface across various scientific communities and interests groups presents an incessant challenge to political and conceptual boundaries. However, the scale and intensity of these interfaces seem to necessitate a reflection over how corresponding governance capacities can be developed. This paper argues that, in addition to existing regulatory approaches, such capacities may be gained through the art of trans-boundary governance, which is not only attentive to the crossing and erosion of particular boundaries but also adept in keeping up with the dynamics among evolving networks of actors.

Keywords Art of governance · Synthetic biology · Boundary · Global governance

Introduction

Synthetic biology raises few, if any, social concerns that are distinctively new (NEST 2005: 18–19; Benner and Sismour 2005). For example, previous public policy research has pointed out that: 'the vast majority of today's biosafety and biosecurity concerns predate synthetic biology and would be substantially the same even if this new field did not exist' (Maurer et al. 2006: 2). Through the application of engineering principles to the design, control and construction of living systems, synthetic biology seeks

to integrate a wide range of research disciplines, such as biology, chemistry, computational science, engineering, information technology and nanotechnology. As such, it has also inherited some of the social concerns that have been associated with its parent disciplines.

However, the sheer scale and intensity of interfaces synthetic biology has instigated across various scientific communities and interests groups seem to have made the challenge to conventional political and conceptual boundaries more prominent. For example, systems of intellectual property rights become ambiguous at the convergence of different industries (Rai and Boyle 2007: 58; Balmer and Martin 2008: 23). A mathematician may become a new regulatory subject to health authorities if he was to develop algorithms for a new generation of cell therapy (Economist 2012). In addition, the possibility of a 'garage biologist', who purchases DNA sequencing equipment from eBay to conduct synthetic biology at home, contests the boundaries between private pastime and public liability. As noted by the OECD and the Royal Society in their joint workshop report (2010: 41), 'synthetic biology is being developed both within and outside of the traditional arenas of science and technology R&D'. Under the banner of synthetic biology, industries that may have previously followed different priorities and been supervised by different sets of rules, may now need to be summoned to the same policy roundtable.

It is this stretching and revamping of our conceptual grid and the subsequent implications for global governance that this paper aims to explore. This paper argues that the border-transcending characteristics of synthetic biology urge us to reflect on the conventional remit of governance. An effective global governance of synthetic biology cannot be an act of simply 'filling the prescription', or formatting the problem to match established policy categories. As

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practitioners of synthetic biology crisscross organizational turf, governance may not be best framed as a rigid regulatory regime, but as a trans-boundary operation that is adaptable to evolving social needs. By ‘trans-boundary’, I mean both the responsiveness to the fluidity of social associations and the transcendence of old institutional limits. Such governance seeks to facilitate effective interactions between the range of current and emerging social actors involved in or affected by scientific and technological developments, to ensure that all parties have the opportunity to express their perspectives and interests at all stages in the pathways of research. Before explicating what a new art of trans-boundary governance may consist of, this paper will first demonstrate a few examples in which synthetic biology challenges conventional perceptions relating to governance.

Contested boundaries

There are at least three sets of boundaries that are of practical concerns for global governance of synthetic biology: (a) positional authorities, (b) scientific disciplines and (c) geopolitical areas.

Positional authorities

To date, the most widely publicised clinical achievement of synthetic biology is perhaps the world’s first synthetic organ transplant carried out in July 2011 in Sweden (Roberts 2012). The artificial windpipe was created with a combination of bioengineering, nanotechnology and stem cell science. Portrayed as the force for a ‘new industrial revolution’ (RAEng 2009), it may not be surprising that explorations of synthetic biology’s medical applications have already been developed simultaneously in a wide range of areas, such as broad-spectrum antibiotics, low-cost diagnostics for waterborne parasites, remedies for celiac disease, tuberculosis, eradication of malaria mosquitos and malnutrition preventions. However, it may not have been expected by many that, in fact, apart from the synthetic windpipe, all the other examples listed above are projects developed by undergraduate students in the international genetically engineered machine (iGEM) competition (c.f. iGEM 2010, 2011 ‘Health & Medicine’ Team Tracks). In other words, while synthetic biology is often regarded as a field that ‘makes biology easier to engineer’, it also facilitate the contribution to scientific innovation from people who are not considered as professional experts in the traditional sense, such as undergraduate students.

To be sure, similar to many other international scientific competitions, iGEM is first and foremost a platform for nurturing talents. Yet, with the caution of not over

accentuating the actual governance impact of the iGEM competition, it is safe to argue that the development of iGEM has contested conventional expectations of experts and beginners’ roles in scientific governance. This in turn may expand governance options in normalizing emerging sciences. Since its first competition in 2004, iGEM has functioned as a global hub for young scientists to meet and compete. Many nations, including China and the UK, have seen taking part in iGEM as a strategic move to promote domestic progress in the life sciences (POST 2008; Zhang 2011). Undergraduates’ annual performances at iGEM contests have been treated as important indicators to assess, reflect on, and criticise national policy making.

The increasing influence iGEM has over the global development of synthetic biology has relied on at least three points that may appear to be “counter-intuitive” to conventional governance approaches. Firstly, iGEM serves as a ‘scientific building block’ (Falkner et al. 2009) that largely depends on unsystematic contributions from ‘beginners’ (students and many of their tutors) rather than established experts. The concept of a ‘scientific building block’ was highlighted in both the studies of nanotechnology and climate change. It refers to a transnational body that defines and characterises new materials, metrology and testing methods, and provides the grounds for internationally standardisation and regulatory convergence (Breggin et al. 2009: 85–87; Falkner et al. 2011). Regulators and experts are conventionally conceptualised as the primary members of such building blocks. However, in the case of synthetic biology, evolving standards, codes of conducts, collections and categorisations of biobricks are at least as much influenced by the iGEM competition as by conventional scientific institutions. During the SB4.0 conference, Ron Weiss expressed the view that although it is not yet clear what synthetic biology is, ‘the process of educating new members of the community through iGEM was a process of learning about synthetic biology’ and ‘the way of moving synthetic biology forward was to move iGEM forward’ (Calvert 2008). In short, ‘beginners’ are at least making as active and valuable contributions as established senior scientists to the international normalisation of synthetic biology.

Secondly, as essentially a ‘scientific’ competition, iGEM plays a crucial role in the ‘social’ engineering of the upcoming generation of young scientists. Although the Registry of Standard Biological Parts at MIT undoubtedly played a major role in forming the open source innovative model, the ‘get and give’ philosophy embraced by iGEM is seen to have significantly promoted global open access culture (OECD and the Royal Society 2010: 25; RAE 2009; Zhang 2011: 304). Meanwhile, iGEM also facilitates global exchange and dissemination of concerns over biosafety, biosecurity, IP regimes, ethics and public engagement in the field of synthetic

biology. Empirical studies carried out by the joint Kings College London and Imperial College Centre for Synthetic Biology and Innovation (CSynBI) have suggested that ‘through participating iGEM competitions, countries like China and Japan, who have not traditionally attended to such issues so early on in the development of scientific fields, appear to be doing so for synthetic biology’ (Zhang et al. 2011: 26).

Thirdly and more importantly, the influence iGEM embodies is not a political endowment by any nation-state or professional community, but has arisen processually, through the external accountability iGEM has developed with various stakeholders around the globe. In fact, when envisaging a governance structure for synthetic biology, few would initially have thought that an undergraduate competition would, or should, play a role. However, currently few policy analyses nowadays would ignore the central role iGEM has over the formation of international research culture in this emerging area (House of Commons 2010; OECD and the Royal Society 2010; RAE 2009).

Primarily an international student competition, iGEM naturally has its limits of regulatory impact. However, the point is to highlight that the iGEM presents but one example in which traditional assignments of roles in the scientific hierarchy may be altered and the normalisation of power may take effect through new channels. Viewed in this perspective, the most profound impact of synthetic biology may not be what it can produce materially, but how it may re-structure the constitution of scientific communities through its development.

Scientific disciplines

Synthetic biology should be seen as multi-lateral interdisciplinary research. It is interdisciplinary because it seeks the collaboration of expertise among previously specialised lines of research. It is multi-lateral because it interconnects different aspects of social and economic practice and calls for consortiums of diverse relevant social actors in resolving problems.

However, the actual practice of interdisciplinarity and knowledge integration cannot be taken for granted. Previous studies on the biological sciences (Bruggren et al. 2010) and health sciences (Terpstra et al. 2010) have both cautioned against a simple assumption that interdisciplinarity only requires ‘good will’ from scientific practitioners. In fact, issues such as disciplinary dependent concepts and vocabularies, difficulty in getting work published and recognised, and institutional barriers to inter-sectoral collaborations (Bruggren et al. 2010: 130; Terpstra et al. 2010: 517–519) may all prevent productive dialogue from taking place. Similar scenarios can also be seen in synthetic biology.

Despite efforts in cultivating a first generation of synthetic biologists through newly-introduced post-graduate courses (POST 2008), at least in the near future, synthetic biology may still rely on the contributions from ready-established ‘parent disciplines’. In fact, a practicality pointed out by Royal Academy of Engineering (2009: 49) is that taking into account the amount of expertise needed, future synthetic biologists will be required to ‘derive their primary peer support and recognition’ before ‘moving into interdisciplinary research’ (RAE 2009: 49).

Consequently, to achieve effective governance, it is more prudent to recognise potential difficulties synthetic biology may encounter in operating and communicating across different scientific fields, rather than assuming it will automatically unify all branches into one. For example, Drew Endy pointed out that a pertinent question in meeting biosafety and biosecurity challenges is how identified risks can be communicated and understood across disciplinary boundaries:

‘...the majority of people coming into synthetic biology aren’t biologists. They’re physicists or computer scientists or electrical engineers and so they’re just of a different culture. They don’t have a lot of experience with microbiological safety. So you need to gain access or transmit knowledge across not just a generational gap, but across cultural divides’. (Endy in Lentzos 2009: 319)

For scientists in the field, such as Endy, the view is not so much that synthetic biology has automatically overcome disciplinary differences, but rather that practitioners have to work with these differences on a day-to-day level. Access to other fields cannot be taken granted but has to be ‘gained’ while knowledge has to be explained, communicated or translated as across different scientific fields.

However bridging disciplinary gaps may imply more fundamental changes in governance strategies than simply creating opportunities for interdisciplinary ‘get-togethers’. For example, even though Research Councils UK has promoted joint-funding initiatives across sectors traditionally governed by the separate (medical, biological, engineering, social, humanities) Research Councils, the Royal Academy of Engineering disapproves of funding schemes in ‘their present form’ as merely ‘familiarising the awardees with the working culture of another discipline’ and failing to facilitate individual researchers to develop more substantive roles across disciplinary borders (RAE 2009: 49). One reason may be that top-down funding alone fails to create incentives for parallel communities (such as biology, engineering or computing communities) to gain mutual trust and responsiveness from each other. Thus, the challenge for governing synthetic biology is not so much about ‘opening up’ policy categories so as to collect an

exhaustive mosaic display of disciplines within the regulatory radar. It is also about how to attend to existing disciplinary or industrial divides and getting the message ‘across’.

Geopolitical areas

Similar to many modern sciences, another practical concern that must be taken into consideration in the governance of synthetic biology is that it is being simultaneously developed in different parts of the world. Subsequently, the progress of synthetic biology is subject to different political regimes that are interwoven with each country’s historically developed R&D system and scientific traditions. For example, while synthetic biology took off in the US with apparent industrial interests (POST 2008; Rodemeyer 2009), the UK’s emphasis is on cultivating ‘cohesive, cross-disciplinary’ research networks (BBSRC 2007). Chinese scientists have sought state sponsorship and nation-wide coordination (Zhang 2011).

However, the global development of synthetic biology is catalyzed by transnational funding programmes. The first synthetic biology project in China was not funded by Chinese sources, but was part of the ‘Programmable Bacteria Catalyzing Research (PROBACTYS)’ funded under the European Commission’s Sixth Framework Programme (Yang 2010). In 2009 the US NSF and UK EPSRC jointly funded five US-UK collaborative projects. The European Commission’s New and Emerging Science and Technology (NEST) Sixth Framework Programme (FP6) and the European Science Foundation’s EuroSYNBIO programme also aimed at encouraging international projects.

Transnational developments are also visible in several governance initiatives, such as the workshop organised jointly by the OECD, the US National Science Foundation and the UK Royal Society in 2009, a joint project between the Austrian Science Fund (FWF) and the National Natural Science Foundation of China (NSFC) on ‘Investigating the biosafety and risk assessment needs of synthetic biology in Austria and China’, and an ongoing project which brings together the six science and engineering academies from the USA, UK and China.

Therefore, a fuller picture of the global development of synthetic biology, as with many other modern sciences, consists of both national particularities and increasingly entangled inter-national relations. These cross-border linkages may be of financial and professional origin, but their implications over governance are at least twofold.

Firstly, while national characteristics can still be traced, and the promotion of related research still relies on regional context and development paths, there is also a growing occurrence of governance propositions produced by multinational groups, cross-border financing strategies, and the

transnational administration of research infrastructure and data. In this sense, one could argue that as transnational communication becomes part of the social condition in scientific research, there is an emerging governmentalization (capacity to govern) of non-state actors.

Secondly, there seems to be an emerging shift of ‘governmentality’, that is to say, a shift in the way in which problems are perceived by different local, national and international authorities, and in the objectives they seek and the strategies and techniques that they choose to pursue (Rose 1999: 20). With the transnationalisation of research funds and scientific networking, different social actors shape the governance of synthetic biology in their own ways; but each of these actors can only ever aspire to partial legitimacy: proximity to research experience, market, resources or political legitimacy does not guarantee entitlement to assume overall authority. It provides each social actor with leverage in exerting their influence, but at the same time such leverage remains partial and contested. Globally speaking, the effective governance of synthetic biology requires not only that nation-states pass down their authority into a plurality of civil institutions and networks, but also requires nation-states to transform their authorities into other transnational agents (such as international conferences, iGEM and other cross-border research initiatives). The governance implications of the emerging empowerment of non-state actors and a potential need for nation-states to govern through and/or alongside transnational agents are further discussed in the following section.

Implications for global governance

Before summarising the various conventional boundaries that synthetic biology may obscure or even alter, let me first illustrate a regulatory contradiction which much grey literature on this subject seems to struggle with. On the one hand, there are cautions over the prospect that ‘evolving synthetic biology research pose[s] a fundamental challenge to the current regulatory structure’ (OECD and the Royal Society 2010: 35; NEST 2005; Parens et al. 2009). While on the other hand, synthetic biology is perceived as ‘covered’ by borrowing national and international regulatory patchworks from GMOs, stem cells, chemicals, cosmetics, biotechnologies, data protection and risk managements (EGE 2009: 27–31). ‘Overall, the existing regulatory framework is working well’ (RAE 2009: 48). To put it more bluntly, while in a general sense, the novelty and scale of synthetic biology research seems to urge that something be done, when the examination of regulatory agendas becomes issue-specific, there always seems to be arguments that nothing else can be added. In other words, challenges experienced by stakeholders on the ground

seem to ‘disappear’ when corresponding regulatory initiatives are weighed at the policy roundtable.

This paradox seems to indicate that seeking the ‘added’ novelty brought by synthetic biology onto pre-conceived regulatory categorisations may be a wrong way in comprehending this emerging science. The characteristic of synthetic biology is not its rupture from previous science, but how it further proliferates the sophistication and hybridity of science by simultaneously crossing positional, disciplinary, sectorial and national divides.

The three examples demonstrated in the previous section all contest a conventional regulatory matrix, and shed light on different aspects an effective global governance should take into account. Firstly, the case of iGEM demonstrates possible challenges to pre-conceived orderliness (e.g. where influence lies) in an emerging science. Effective governance, then, should not be pursued along the line of prescribing how things should be, but to elicit and steer potential ways in which things could be. Secondly, the ability of working across borders is of practical advantage in multi-lateral interdisciplinary research. While the atlas of science may still be represented by different disciplinary territories, synthetic biology rewards those who can command the language on the other side of their boundaries. Good governance should incentivise these cross-border efforts. Finally, as it is increasingly difficult to make clear the separation between funding and regulation of scientific practice from one geopolitical area to another, the blurring of boundaries in the transnational collaborations of synthetic biology also signifies the emergence and potential entanglements of new non-state governing actors.

To paraphrase Marshall McLuhan’s famous insight on modern media, ‘the medium is the message’. For synthetic biology, ‘boundary-crossing is the message’. In other words, the practice of synthetic biology embeds itself in the message, or scientific prospect, to be understood. This in turn creates a symbiotic relationship by which the practice of science influences how the science should be received and governed.

The art of trans-boundary governance?

Bearing in mind the above, this section argues that the global development of synthetic biology may require a new ‘art’ of trans-boundary governance. By ‘art’ I mean a ‘style of governing’ with the aim to ‘regulate infrastructures... and to delegate powers’ to relevant groups (Osborne 1997: 175; 183). Corresponding to issues raised by the three examples, this section examines three questions: (1) How should we address the need for cross-border communication? (2) What new forms of governing intelligence should be highlighted? And (3) What should be left to network

actors to ‘improvise’? The aim of the following discussion is not to suggest a replacement for exiting national or transnational regulatory programs, but to provide a complementary perspective which would enable a more pertinent and adaptable governing framework.

Reorienting the focus of governance and promoting communication

Almost all existing policy reviews on synthetic biology open up their discussion with this question: what is the definition of synthetic biology? The logic is that one could not regulate something without first stating exactly what ‘the thing’ is. For some, such as the European Group on Ethics in Science and New Technologies (EGE 2009: 48, see also 36), ‘an internationally recognised definition of synthetic biology’ is a prerequisite for sound regulation. However, in practice, this precondition of having an universally agreed definition may hamper rather than help the development of regulations. It has been highlighted that current regulations are ‘commonly assumed’ as adequate ‘because it is not possible to define new fields neatly and draw boundaries around what is included or excluded’ (OECD and the Royal Society 2010: 12).

Yet rather than setting back the governance progress for the absence of a perfect definition of ‘synthetic biology’, an alternative view may be if one sees the subject of governance not as an ‘object’, but as ‘interactions’. For governance is not about imposing characterisation onto social practices, but about guiding the synergy among social practices. The same research practice may be recognised as ‘synthetic biology’ by some and as ‘classic chemistry’ or ‘genetic research’ by others. Instead of getting electronic engineers and geneticists to all concede on the labelling of certain conducts, a more effective governance approach may be to equip stakeholders with how effective coordination can be made with people outside their own field.

This may complement existing scientifically informed policies, or rather, stitch together regulatory patchworks currently dispersed among the various ‘parent’ fields for synthetic biology. For example, instead of instructing research practitioners by attempting to set out definitions for types of activity, and a formal ‘code of conduct’ or set of ‘guidelines’, it may be more fruitful in establishing a set of ‘guide questions’ with the dual aim of helping to facilitate stakeholders’ communication with others (what they should be aware of and entitled to know) and of clarifying stakeholders’ accountabilities (under what condition their remit begins and ceases). In this sense, governance is not merely an embodiment of reflexivity, but the continuous provocation of reflexivity among stakeholders. This may, as in the case of disciplinary divides, help to get the ‘message’ across previous professional divides or even

incentivise different professions in co-producing research norms. This is in line with the notion of ‘adaptive governance’ (Brunner and Steelman 2005), which argues that in addition to legal frameworks of ‘hard laws’, effective governance should also accommodate ‘soft rules’ which are sensitive to developing relations among stakeholders and encourage dialogues and mutual learning at various levels.

New form of governing intelligence

Contemporary science challenges and reconstructs the traditional relationship between regulator and those regulated and between decision-makers and those affected by the decisions. This is even more so in the case of synthetic biology. As the effect of transnational funding, professional and commercial networks have become ever far-reaching, the appropriateness of national governance becomes a mediation between domestic needs and international trends.

While there is shared support for encouraging what political scientists term ‘a pluricentric form of governance in which decision making involves a plurality of actors, arenas and processes’ (Sorensen and Torfing 2009: 255), it is key to ensure that governance, either at the local, regional or global level, does not become adrift amongst competing interests and maintains a realistic vision of development needs. On this point, it is emphasised that ‘partnership with civil society groups, social scientists and ethicists should be pursued as a highly effective way of understanding critical issues’ concerning synthetic biology, which may in turn contribute to more pertinent regulatory schemes (Balmer and Martin 2008).

Yet, despite the good will, the continuous requests for better public deliberation (RAE 2009; EGE 2009; House of Commons 2010) seem to indicate that in practice the goal to ‘enable the voice of different sectors of society, typically non-specialists...to inform and influence the development’ (RAE 2009: 47) of synthetic biology is yet to be realised. In fact, one study has highlighted the fact that the influence existing forms of committee reports and civil group recommendations have on European synthetic biology community is far from satisfactory (Kelle 2007). Recent European regulatory culture has been criticised by Torgersen (2009: 12, 15) as ‘incorporating stakeholders’ in ‘talking over governance’, rather than having public opinions ‘embedded’ in the governance of research development. In short, despite the growing attentiveness to engaging with wider non-state actors, practice seems to resemble mostly a variation of broad-base conversation, or worse, public education.

Current national policies and transnational agendas may well have implicitly incorporated a variety of public input.

The problem is that few of these inputs are traceable or credited to ‘voice of different sectors of society’ (RAE 2009: 47). If regulation bluntly collects and transforms diverse opinions into a uniform voice, it misses important governing intelligence on the linkage and interconnections between social actors. Valuable intelligence to scientific governance should not be limited to outcomes, such as ‘who did what’, but needs to be equally attentive to relation-tracing on ‘who did what to whom’. The mapping of the sources of pressures, channels of demands, and conduits of negotiations is important in tackling ineffective engagements, for it facilitates a better grasp of the asymmetry of power and avenues of dialogues on the ground.

To put it in another way, for any ‘pluricentric form of governance’ (Sorensen and Torfing 2009: 255) to be effective, helping social actors to develop respective power-leverage and having their voices heard are a necessity. But the knowledge of a ‘topography’ of power-leverages at work is just as important. This is to say, governing bodies should make visible the ways in which various sources of opinions are incorporated into governing strategies, the where and the how of such incorporation, and the ways in which effects over time can be made evident, and practice and mechanisms modulated in the light of experience. This would not only vindicate various civil contributions, but also help to make sense and monitor the traffic in the entangled web of interests.

What should be left to network actors to ‘improvise’?

So far, this paper has demonstrated that the art of trans-boundary governance would take on a relational focus and be attentive to the topography of power-relations in the development of regulatory strategies. What it does not propose to do, however, is to (pre)determine which social institution(s) should be entitled to and entrusted with the task of governing scientific practice. Indeed as the development of synthetic biology relies on continuous input from an expanding range of social actors, its governance reality resembles less of a traditional ‘technocratic decision model’ and more of a ‘palaver model’, in which it is ‘unclear who may not contribute to the discussion’ (Beck 2007[2009]:125; emphasis added). In other words, it may not be surprising to see that the list of stakeholders from diverse fields will only get longer, as synthetic biology expands its applications. This raises the problem of how to best incorporate and/or accommodate networks of stakeholders as science develops.

The question of who to include (and consequently exclude) in the governance of science, technology and risk is one that many existing regulatory initiatives have attempted to resolve—for instance what role should pressure groups, activists, religious minorities and so forth be

assigned to in these processes. But traditional chain-of-command rationales, or a simple centre-periphery 'order' around leading institutions (government, scientific community or professional agencies), seem to be insufficient. For in the case of new technologies, social authority is dispersed among diverse, and sometimes incomparable, social sectors, whose influence over other actors remains partial, contested and often inconsistent. It has long been acknowledged that a governance framework may be better constructed on a 'power with' rather than 'power over' model (Guinier in Slaughter 2004: 207). The UK's effective governance on stem cell research has confirmed the benefits of 'powering with' key institutions. For example, the UK's Human Tissue Authority has not been the host, but a participant within a number of networks that span across scientific, ethical, regulatory and industrial communities (HTA in House of Commons 2010: Ev125).

Apart from strengthening governance capacity by broadening regulatory networks, synthetic biology may further add a 'temporal' dimension to the idea of 'power with'. This is to say, it may require a governance ethos that is not limited to embracing established groups across professional spectrums, but is also ready to acknowledge, incorporate and exploit unexpected or not-yet-conceivable 'governance bodies in-the-making'.

The case of iGEM is only but one of such example. It is too premature to conclude what enduring influence iGEM would exert in the global governance of synthetic biology. Yet the growing attention iGEM has attracted internationally clearly indicated the possibility and practicality of a non-previously-conceived (or even imagined), self-evolving student associations in contributing to the global governance of science. Rather than institutionally designing a calculated regulatory efficiency, it may be better to leave the regulatory structure open-ended and see what network interactions would 'improvise'.

Thus, for the governance of synthetic biology, instead of establishing a (or a set of) pre-configured international governance institution(s), efforts may be better spent in close monitoring of and responding to the evolving regulatory roles of various interests-related bodies. National science and technology authorities and certain transnational organizations (e.g. funding agencies and professional associations) may have an advantage in conducting large-scale long-term monitoring. Instead of disputing what should be the leading institution or who should be given more regulatory credits, the realpolitik of synthetic biology may benefit more from tracking and periodically reviewing, adjusting and publicising the evolving collection of regulatory bodies at work. This may provide better stewardship for small domestic stakeholders to comprehend the global map of emerging science and clearer guidance in transnational coordination.

Conclusion

Synthetic biology is often characterised as an emerging 'hybrid discipline' which combines 'elements of both engineering and science to achieve its goal of engineering synthetic organisms' (Adrianantoandro et al. 2006: 12). Subsequently it presents many social and ethical concerns similar to that of the disciplines it assimilates, such as biosecurity and bioterrorism concerns in genetic research, the debate on what constitutes life in stem cells, intellectual property right protections in information technology and global justice debates in pharmaceutical industries, etc. Much has been written on how each concern may be handled individually in different contexts. This paper takes an alternative approach and highlights a more general challenge embedded in synthetic biology, which holds a key in effective response to many specific concerns but has not fully been reflected in policy discussions. Similar to many other convergent sciences, this embedded challenge of synthetic biology is that it contests conventional boundaries in which governance operates, such as positional, disciplinary and geopolitical categorisations.

To meet such challenges and to help bridge existing regulatory patchworks, this paper argues for an 'art' of trans-boundary governance, which is not only attentive to boundary eroding or boundary crossing situations, but is also adept in keeping up with the dynamics among evolving networks of actors. For the field of synthetic biology constitutes a loosely connected network of actors and organisations, some of which may still be 'in-the-making'. It may alter the boundaries of responsibility and authorities commonly assigned to certain roles, such as in the case of iGEM competition. It may lift researchers out of their comfortable establishment of practices, and make working cross disciplinary cultures a norm. It may also transcend geopolitical borders. Interest-related parties, including national sovereignty, are only one set of the authorities in the entangled web of global stakeholders.

More specifically, this paper has pinpointed three areas which may contribute to the good governance of synthetic biology: (a) Governance should take on a relational focus, which substantiates an emerging relation between stakeholders not by prescribing guidelines but by pinpointing to them questions that may imply shared responsibilities. (b) In line with a relational focus, a topography of sources of influences and communicative channels at work provides important governing intelligence, for it is key in directing effective engagements with various stakeholders. (c) It may not be wise to pre-determine the governance remits of and to ascribe roles to stakeholders. For the legitimacy and political influence of any given actor in governing synthetic biology can no longer be calculated in advance according to some fixed scale. Rather it requires to

be gained in situ through successions of cross-border communications and undertakings. Thus efforts may be better spent in responding to the evolving regulatory roles of various interests-related bodies and the power-leverage in-between them. In short, the reality of synthetic biology may benefit more if current scientific bureaucracy is supplemented with specific responsiveness to its impending contestation of governing and conceptual boundaries.

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References

- Adrianantoandro E, Basu S, Karig DK, Weiss R (2006) Synthetic biology: new engineering rules for an emerging discipline. *Mol Syst Biol* 2:1–14
- Balmer A, Martin P (2008) Synthetic biology: social and ethical challenges. An independent review commissioned by the Biotechnology and Biological Sciences Research Council. http://www.bbsrc.ac.uk/web/FILES/Reviews/0806_synthetic_biology.pdf. Accessed 25 Jun 2012
- BBSRC (2007) Networks in synthetic biology. <http://www.bbsrc.ac.uk/funding/opportunities/2007/synthetic-biology.aspx>. Accessed 25 Jun 2012
- Beck U (2007 [2009]) *World at risk* (2009 English edition). Polity Press, London
- Benner SA, Sismour AM (2005) Synthetic biology. *Nat Rev Genet* 6:533–543
- Breggin L, Falkner R, Jaspers N, Pendergrass J, Porter R (2009) Securing the promise of nanotechnologies: towards transatlantic regulatory cooperation, Sept 2009. Report, Chatham House, London, UK
- Bruggen W, Chapman K, Keller B, Monticino M, Torday R (2010) Biological sciences. In: Frodeman R, Klein J, Mitcham C (eds) *Oxford handbook of interdisciplinarity*. Oxford University Press, Oxford
- Brunner RD, Steelman TA (2005) Beyond scientific management. In: Brunner RD, Steelman TA, Coe-Juell L, Cromley CM, Edwards CM, Tucker DW (eds) *Adaptive governance: integrating science, policy and decision making*. Columbia University Press, New York
- Calvert J (2008) SB4.0—a social scientist's perspective. Synthetic biology standards network. <http://www.synbiostandards.ac.uk/comment.php?id=3>. Accessed 25 Jun 2012
- Economist (2012) Computing with soup. *Economist*, 3 Mar 2012. <http://www.economist.com/node/21548488>. Accessed 25 Jun 2012
- EGE (The European Group on Ethics in Science and New Technologies to the European Commission) (2009) Ethics of synthetic biology. Opinion No. 25, 17 Nov 2009. EGE, Brussels
- Falkner R, Breggin L, Jaspers N, Pendergrass J, Porter R (2009) Regulating nanomaterials: a transatlantic agenda, September 2009 Chatham House Briefing Paper. Chatham House, London
- Falkner R, Vogler J, Stephan H (2011) International climate policy after Copenhagen: towards a 'building blocks' approach. In: Held D, Hervey A, Theros M (eds) *The governance of climate change: science, politics and ethics*. Polity Press, London
- House of Commons Science and Technology Committee (2010) Bioengineering: seventh report of session 2009–10, report, together with formal minutes, oral and written evidence, 17 Mar 2010. Stationary Office Limited, London
- Kelle A (2007) Synthetic biology & biosecurity: awareness in Europe. Bradford Science and Technology Report No. 9, Nov 2007. IDC, Vienna
- Lentzos F (2009) Synthetic biology in the social context: the UK debate to date. *BioSocieties* 4(2–3):303–315
- Maurer SM, Lucas KV, Terrell S (2006) From understanding to action: community-based options for improving security and safety in synthetic biology, 15 Apr 2006, UC Berkeley. <http://gspp.berkeley.edu/iths/UC%20White%20Paper.pdf>. Accessed 25 Jun 2012
- NEST (2005) Synthetic biology: applying engineering to biology, Report of a NEST High-Level Expert Group. Office for Official Publications of the European Communities, Luxembourg
- OECD and Royal Society (2010) Symposium on opportunities and challenges in the emerging field of synthetic biology: synthesis report. <http://www.oecd.org/dataoecd/23/49/45144066.pdf>. Accessed 25 Jun 2012
- Osborne T (1997) On health and statecraft. In: Petersen A, Buntun R (eds) *Foucault: health and medicine*. Routledge, London
- Parens E, Johnston J, Moses J (2009) Ethical issues in synthetic biology: an overview of the debates, SB3.0, Jun 2009. Woodrow Wilson International Centre for Scholars, Washington
- POST (UK Parliamentary Office of Science and Technology) (2008) POSTNOTE: synthetic biology, Jan 2008, No 298. POST, London
- Rai A, Boyle J (2007) Synthetic biology: caught between property rights, the public domain and the commons. *PLoS Biol* 5(3):e58
- Roberts M (2012) Surgeons carry out first synthetic windpipe transplant. BBC News, 7 Jul 2012. <http://www.bbc.co.uk/news/health-14047670>. Accessed 25 Jun 2012
- Rodemeyer M (2009) New life, old bottles: regulating first-generation products of synthetic biology, SB2.0, Mar 2009. Woodrow Wilson International Centre for Scholars, Washington
- Rose N (1999) *Powers of freedom: reframing political thought*. Cambridge University Press, Cambridge
- Royal Academy of Engineering (2009) Synthetic biology: scope, applications and implications. Royal Academy of Engineering, London
- Slaughter A (2004) *A new world order*. Princeton University Press, Princeton
- Sorensen E, Torfing J (2009) Making governance networks effective and democratic through metagovernance. *Public Adm* 87(2):234–258
- Terpstra JL, Best A, Abrams D, Moor G (2010) Interdisciplinary health sciences and health systems. In: Frodeman R, Klein J, Mitcham C (eds) *Oxford handbook of interdisciplinarity*. Oxford University Press, Oxford
- Torgersen H (2009) Synthetic biology in society: learning from past experience? *Syst Synth Biol* 3:9–17
- Yang H-M (2010) Synthetic biology and the future of man. Presented at the international symposium on opportunities and challenges in the emerging field of synthetic biology. Washington DC, 9–10 Jul 2009
- Zhang JY (2011) The “National” and “Cosmos”: the emergence of synthetic biology in China. *EMBO Rep* 12(4):302–306
- Zhang JY, Marris C, Rose N (2011) The transnational governance of synthetic biology: scientific uncertainty, cross-borderness and the ‘art’ of governance. BIOS Working Paper, BIOS, London School of Economics and Political Science, London

Websites

- iGEM (2010) ‘Health&Medicine’ Team Tracks. http://igem.org/Team_Tracks?year=2010. Accessed 25 Jun 2012
- iGEM (2011) ‘Health&Medicine’ Team Tracks. http://igem.org/Team_Tracks?year=2011. Accessed 25 Jun 2012