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Abstract

A number of commentaries preoccupied with the legal, social and ethical implications of synthetic biology have emphasised that an important element shaping options for its future governance will be the normative ethos that is adopted by the emerging field. One venue that has regularly been identified as central to the development of this normative ethos is the International Genetically Engineered Machine (iGEM) Competition, an annual synthetic biology competition, which attracts thousands of students from across the world. The ideal values promoted by iGEM of collaboration, interdisciplinarity, sharing of results, and overt commitment to the consideration of social and ethical implications of scientific work, are frequently interpreted as offering a model for the future development of the field. In the discussion that follows it will be noted that many of iGEM's normative aspirations appear to be difficult to convert into practice and that many of the paths which various forms of synthetic biology appear to be following deviate from the types of values iGEM publicly promotes. Policy makers are invited to make a more realistic assessment of iGEM's capacity to contribute (via generating a distinct synthetic biology normative ethos) to the future governance of the emerging field.

Keywords

igem, machine, engineered, genetically, competition, international, identity, counter, norms, biology, synthetic, governance

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'iDENTITY' AND GOVERNANCE IN SYNTHETIC BIOLOGY: NORMS AND COUNTER NORMS IN THE 'iNTERNATIONAL GENETICALLY ENGINEERED MACHINE' (iGEM) COMPETITION

DAVID MERCER*

A number of commentaries preoccupied with the legal, social and ethical implications of synthetic biology have emphasised that an important element shaping options for its future governance will be the normative ethos that is adopted by the emerging field. One venue that has regularly been identified as central to the development of this normative ethos is the International Genetically Engineered Machine (iGEM) Competition, an annual synthetic biology competition, which attracts thousands of students from across the world. The ideal values promoted by iGEM of collaboration, interdisciplinarity, sharing of results, and overt commitment to the consideration of social and ethical implications of scientific work, are frequently interpreted as offering a model for the future development of the field. In the discussion that follows it will be noted that many of iGEM's normative aspirations appear to be difficult to convert into practice and that many of the paths which various forms of synthetic biology appear to be following deviate from the types of values iGEM publicly promotes. Policy makers are invited to make a more realistic assessment of iGEM's capacity to contribute (via generating a distinct synthetic biology normative ethos) to the future governance of the emerging field.

I INTRODUCTION

The International Genetically Engineered Machine (iGEM) competition is considered instrumental in the building of the discipline of synthetic biology. It was initiated at the Massachusetts Institute of Technology (MIT) in 2003 for undergraduate students, and has rapidly grown in popularity. It has played an essential role making synthetic biology an international discipline. It appeals to young minds and has captured the attention of industry academics and governments.[1]

In the following paper I will examine the significance of the International Genetically Engineered Machine (iGEM) Competition for the future governance and regulation of synthetic biology. IGEM's relevance to these questions is normally framed in terms of its importance as a venue for the development of the normative identity of the future synthetic biology scientist.[2]

Proposals for the regulation and governance of synthetic biology can be divided according to whether or not they operate within Ethical Legal and Social Implications (ELSI) traditions of

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1 Office of Economic Cooperation and Development (OECD), *Emerging Policy Issues in Synthetic Biology*, (OECD Publishing, 2014) 19, see also 3, 17, 25, 27.

2 A brief history of iGEM will be provided below in Section IV. The acronym iGEM will be used in the following paper to refer to the iGEM competition.

policy analysis or form part of new post-ELSI approaches.[3] A feature of both approaches have been significant preoccupations with issues surrounding what types of norms and ethical codes of practice are appropriate for the emerging field of synthetic biology.

Funding for the study of ELSI of new genetics was formalised in 1990 as part of the Human Genome Project. ELSI research has been preoccupied with the construction of policies addressing the implications of the new genetics for areas such as privacy, clinical medicine, informed consent, intellectual property and biosecurity.[4] In the United States, the National Science Foundation has mandated that large Nanotech and synthetic biology research incorporate ELSI dimensions. Similar initiatives have also appeared in a variety of forms in Europe and the UK.[5]

Recent critiques of ELSI approaches have suggested they risk being limited to analysing the social impacts of scientific research at a distance from its sites of creation, and after the research has already begun to develop momentum. This means questions as to how the research might be being framed, and conducted to start with, are too easily back-staged. This has led to a call for post-ELSI approaches that emphasise the need for more flexible, 'reflexive', and collaborative ethical and social engagement between scientists, social scientists, regulators, and the public, as early as possible in the development of scientific projects, and in close proximity to where research is being carried out.[6]

ELSI and post-ELSI studies have resulted in a wealth of literature concerned with the regulation and governance of synthetic biology. One recent account notes that at least 40 major reports have been produced over the last decade, or so, since synthetic biology's emergence.[7] Part of the impetus for such regulatory preoccupations have been perceptions, particularly in the UK and Europe, that recent attempts for the introduction of Genetically Modified (GM) products and processes were not well managed by regulators, leading to unnecessary controversy – a situation hoped to be avoided in the future.[8]

Both approaches (which in practice may not always be as distinct as some proponents suggest) have evolved within a broader tradition of governance of biotechnology influenced

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3 In this context it is also important to note the more radical position taken by various NGO's for a moratorium on synthetic biology. See for example: Friends of the Earth, CTA, ETC GROUP, *The Principles for the Oversight of Synthetic Biology* (2014) <http://www.etcgroup.org/sites/www.etcgroup.org/files/The%20Principles%20for%20the%20Oversight%20of%20Synthetic%20Biology%20FINAL.pdf>.

4 See US National Library of Medicine, *What Are Some of the Ethical, Legal, and Social Implications Addressed by the Human Genome Project?* (8 June 2015) Genetics Home Reference <ghr.nlm.nih.gov/handbook/hgp/elsi>; Michelle Garfinkel et al, *Synthetic Genomics: Options for Governance* (October 2007) J Craig Venter Institute <http://www.jcvi.org/cms/research/projects/syngen-options/overview>; Andrew Balmer and Paul Martin, Biotechnology and Biological Sciences Research Council, University of Nottingham, *Synthetic Biology: Social and Ethical Challenges* (May 2008) <http://www.bbsrc.ac.uk/documents/0806-synthetic-biology-pdf/>.

5 Fillipa Lentzos, 'Synthetic Biology in the Social Context: The UK Debate to Date' (2009) 4 *Biosocieties* 303; Daniel Barben et al, 'Anticipatory Governance of Nanotechnology: Foresight, Engagement, and Integration' in E Hackett et al, *Handbook of Science and Technology Studies* (MIT Press, 3rd ed, 2007).

6 See James Wilsdon and Rebecca Willis, *See-Through Science: Why Public Engagement Needs to Move Upstream* (Demos, 2004); Andy Balmer et al, *Towards a Manifesto for Experimental Collaborations between Natural and Social Scientists* (3 July 2012) Experimental Collaborations <http://experimentalcollaborations.wordpress.com>. For a more critical view see David Mercer, 'Human Practices and the Challenges of Upstream Engagement in Synthetic Biology' in A Bamme et al, *2011 Yearbook of the Institute of Advanced Studies on Science Technology and Society'* (Profil, 2012) 67.

7 Joy Zhang, Claire Marris and Nikolas Rose, 'The Transnational Governance of Synthetic Biology – Scientific Uncertainty, Cross-Borderness and the "Art" of Governance' (BIOS Working Paper No 4, London School of Economics and Political Science, May 2011) <https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2011/4294977685.pdf> ('BIOS report').

8 Lentzos, above n 5.

by the Asilomar conference held in 1975.[9] The Asilomar Conference was initiated by Stanford University biologist Paul Berg to explore the issues involved in the future regulation of emerging recombinant DNA research: recombinant DNA referring to DNA that is produced from the combination of genetic materials from more than one source. Most commentators suggest an important outcome of Asilomar was the inauguration of a model for scientists in the field of biotechnology, to be pro-active in relation to issues of governance and regulation. This took the form of the development of biosafety protocols by scientists prior to external regulation, providing classifications for risk levels and appropriate commensurate safeguard strategies, and supplying advice and input into forms that national advisory bodies and oversight might take.[10] These traditions for scientists to have pro-active interest in regulation and promote ideals of self-governance have continued in the efforts of leading synthetic biology scientists such as J Craig Venter. Whilst he might be accused of displaying some hubris, Venter has been forward in reminding regulators of these efforts. In his testimony to a US Senate hearing in 2010, he notes for the record: 'My teams at both the JCVI and at the SGI have, as the leaders of this field, been driving these ethical and societal implications since the beginning of the research (for nearly 15 years).'[11]

These interests in pro-active engagement of scientists with ELSI issues and their calls for minimal external or scientific self-governance has encouraged a considerable amount of regulatory commentary to consider what types of ethical education, codes of practice and professional ethos might be required to be developed in tandem with these aspirations.[12] Because discussions about the development of codes of practice and professional institutions in synthetic biology involve concerns with education and the emergence of a professional ethos, iGEM, as a novel education venue unique to the field of synthetic biology, has been an obvious source of interest in terms of considering how it might contribute to these developments.[13]

Many post-ELSI approaches have shared these interests in the importance of the links between the development of the 'ethical' normative character of the emerging synthetic biologist and forms of scientific self-governance. In many of these approaches, these interests have been conceptualised slightly differently seeking to augment things like ethical education, codes of conduct, and professionalisation with the development of new forms of collaboration between scientists and social scientists, policy makers and the public. Ideally, these new forms of collaboration should feed back into the development and future governance of the field. These approaches also frequently suggest that the novelty of the field of synthetic biology, emerging as it is at a time of increasingly global and interdisciplinary

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9 See Bjorn Kara Myskja, Rune Nydal and Anne Ingeborg Myhr 'We Have Never Been ELSI Researchers – There is No Need for a Post-ELSI Shift' (2014) 10 *Life Sciences, Society and Policy* 9.

10 Steven Yearley, 'The Ethical Landscape: Identifying the Right way to Think About the Ethics and Societal Aspects of Synthetic Biology Research and Products' (2009) 6 *Journal of the Royal Society Interface* 559.

11 J Craig Venter, *Prepared Statement of J Craig Venter, PhD – President, J Craig Venter Institute – Before the US House of Representatives Committee on Energy and Commerce* (27 May 2010) US House of Representatives – Democrats: Committee on Energy and Commerce <http://democrats.energycommerce.house.gov/sites/default/files/documents/Testimony-Venter-HE-EC-Synthetic-Genomics-Developments-2010-5-27.pdf>.

12 Lorna Weir and Michael J Selgelid provide a good example of governance approaches which have raised the importance of the development of an appropriate synthetic biology professional ethos: 'By ethos we mean the sense of attachment and commitment that persons feel to the groups of which they form a part ... The formation of an ethos for synthetic biology would involve the emergence of a distinctive way of thinking and feeling for members of that profession. The professional ethos would also orient synthetic biologists to their work as an ongoing ethical task.' Lorna Weir and Michael J Selgelid, 'Professionalization as a Governance Strategy for Synthetic Biology' (2009) 3 *Systems Synthetic Biology* 91, 95 (citations omitted). However, it should be noted Weir and Selgelid do not single out iGEM specifically, instead drawing broader analogies with the professionalisation of Engineering and Medicine.

13 For example see OECD, above n 1.

science, demand new ways of thinking about regulatory issues.[14] A number of post-ELSI scholars have been attracted to iGEM as an ideal site to explore the possibilities of new forms of collaboration between social scientists, scientists, and policy makers in synthetic biology more generally. Research has involved forms of ethnography, including participant observation in the competition as student mentors and competition judges, and producing analytical commentaries reflecting on policy implications of these engagements for the field more generally. This work provides an invaluable resource for the analysis that follows.[15]

A conspicuous feature of both traditional and more novel discussions of regulation of synthetic biology, then, have been preoccupations with governance options that aspire to avoid simply continuously expanding formal legal guidelines and oversight. This in turn has inspired numerous discussions about what might be involved in the development of the future identity of the synthetic biology scientist who will be exercising ethical judgement, engaging in new practices and developing new norms and professional identity.

The discussion that follows will be structured in the following way: In Section II, I will provide two brief examples where recent reports exploring regulation and governance of synthetic biology have noted the importance of normative ethical education and the iGEM. In Section III, I will provide an overview of work in the sociology of science, which has investigated the idea of professional norms. I will highlight that a feature of this work is a recognition that claims about professional norms are frequently difficult to sustain in practice. In Section IV, I will provide a brief history of the iGEM. In Section V, I will present a critical analysis of a number of rhetorical claims made by iGEM supporters about the types of normative orientations the competition is meant to be promoting. It will be suggested that iGEM may not be as well suited to the task of developing a normative identity for the future synthetic biology scientist as many commentaries suggest. It will be shown that the competition operates in a social context that encourages a variety of competing and contradictory normative orientations. In Section VI, I will suggest that whilst iGEM may well be contributing to the development of one branch of synthetic biology in general terms, many policy commentators risk overrating its significance as a venue for the development of a normative ethos that will answer the broader ethical and social concerns linked to the fields' emergence.

II iGEM 'RESPONSIBLE STEWARDSHIP' AND THE 'ART OF GOVERNANCE'

Let me provide two examples where recent proposals for the regulation and governance of synthetic biology have highlighted the importance of initiatives to develop appropriate scientific norms and ethical education to which it is anticipated iGEM will contribute. The first example is drawn from a report primarily working within a traditional ELSI framework, *New Directions: The Ethics of Synthetic Biology and Emerging Technologies*, prepared by the Presidential Commission for the Study of Bioethical Issues (PCSBI report).[16] The second example is drawn from a report framed by a post-ELSI approach, *The Transnational Governance of Synthetic Biology* (BIOS report). Produced by the Centre for the Study of Bioscience, Biomedicine, Biotechnology and Society, and funded by the Royal Society, it

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[14] P Rabinow and G Bennett, *Designing Human Practices: An Experiment with Synthetic Biology* (University of Chicago Press, 2012).

[15] Emma Frow and Jane Calvert, 'Can Simple Biological Systems be Built from Standardized Interchangeable Parts? Negotiating Biology and Engineering in a Synthetic Biology Competition' (2013) 5 *Engineering Studies* 42; Andrew Balmer and Kate Bulpin, 'Left to their Own Devices: Post-ELSI, Ethical Equipment and the International Genetically Engineered Machine (iGEM) Competition' (2013) 8 *Biosocieties* 311.

[16] Presidential Commission for the Study of Bioethical Issues, *New Directions: The Ethics of Synthetic Biology and Emerging Technologies* (December 2010) <http://bioethics.gov/sites/default/files/PCSBI-Synthetic-Biology-Report-12.16.10_0.pdf> ('PCSBI report').

refers to the concept of the 'Art of Governance' (with iGEM as part of the process of governance in the making).[17]

A *The PCSBI Report*

The PCSBI report, called by President Obama in the wake of the Venter Institute's claims to have produced the first fully synthetically generated life-form, explores the challenges faced in regulating new forms of life, environmental implications of the controlled release of genetically altered organisms into the environment, and bio-security and intellectual property (IP) implications of synthetic biology.[18] It also notes that these regulatory challenges have been intensified by the widening of both the locations, locally and globally, where synthetic biology research can take place and the credentials of parties who are able to engage in it. As such the report supports the need for continuing development of forms of surveillance over the sourcing of various biological materials and techniques.

The report, nevertheless, does not suggest the situation requires radical changes to existing approaches to regulatory policies involving biotechnology that have evolved since Asilomar.[19] A feature of the tone of the report is the adoption of a responsive and moderate, but permissive, attitude to answering questions of the regulation and governance of synthetic biology. For example, rather than pro-action or precaution, it suggests there should be a 'middle course' approach of 'prudent vigilance'.[20] The report also notes the importance of promoting 'intellectual freedom and responsibility' and 'regulatory parsimony', so regulation is only considered where completely necessary: 'With sufficient freedom to operate, tomorrow's achievements may render moot the risks of today. Self-regulation also promotes a moral sense of ownership within a professional culture of responsibility.'[21]

Underpinning these strategies, the report suggests the need to develop a culture amongst synthetic biology scientists compatible with 'responsible stewardship'. This is explained in the following terms:

> Responsible conduct of synthetic biology research, like all areas of biological research, rests heavily on the behaviour of individual scientists. Federal oversight can guide the development of a culture of responsibility and accountability, but it also must be translated into practice at the laboratory level – and by the institutions that sponsor that laboratory science ... Creating a culture of responsibility in the synthetic biology could do more to promote responsible stewardship in synthetic biology than any other single strategy.[22]

The report goes on to emphasise the role of ethics committees, and ethics education, as key components in creating the responsible synthetic biology scientist. It notes the need to

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17 See 'BIOS report', above n 7.

18 Daniel G Gibson et al, 'Creation of Bacterial Cell Controlled by a Chemically Synthesized Genome' (2010) 329 *Science* 52 <http://www.sciencemag.org/cgi/rapidpdf/science.1190719v1.pdf>.

19 Whilst there has been a mass of reports looking at policy aspects of synthetic biology over the last decade most regulatory approaches tend to have operated incrementally and avoided treating synthetic biology as exceptional. Sarah R Carter et al, 'Synthetic Biology and the US Biotechnology Regulatory System: Challenges and Options' (Report, J Craig Venter Institute, May 2014); OECD, above n 1; Yearley, above n 10.

20 The avoidance of the Precautionary Approach might be envisaged as a response to the calls for its strong application to synthetic biology including a moratorium on areas of synthetic biology research by a variety of NGOs. See for example: Friends of the Earth, CTA, ETC GROUP, above n 3; Richard C Lewontin, 'The New Synthetic Biology: Who Gains?' (8 May 2014) *The New York Review of Books* <http://www.nybooks.com/articles/archives/2014/may/08/new-syntheti'c-biology-who-gains/>; Gregory Kaebnick, 'Carefully Precautionary about Synthetic Biology? (22 March 2012) *Bioethics Forum* <http://www.thehastingscenter.org/Bioethicsforum/Post.aspx?id=5781&blogid=140>.

21 PCSBI report, above n 16, 28.

22 Ibid 133.

import key aspects of this culture, which are largely already present in clinical, biological, and biomedical research, into engineering research. The PCSBI report notes the significance of iGEM as a venue for the education of the next generation of synthetic biology scientists and also as a vehicle to educate the public about synthetic biology: 'Beyond building biological systems, the broader goals of iGEM include growing and supporting a community of scientists guided by social norms.'[23]

B *The BIOS Report*

The BIOS report explores the implications of synthetic biology's 'borderlessness', literally in terms of geographic place, but also more abstractly, in terms of the unsettled boundaries of professional identities and scientific uncertainty. It suggests 'borderlessness' arises for the following types of reasons:

- In a rapidly globalising scientific world, numerous synthetic biology activities rely on free access to scientific information online, a domain notoriously difficult to regulate.
- Numerous scientific and social uncertainties are involved in emergent novel collaborative practices for doing research such as iGEM and DIYbio (Do it Yourself, garage or hacker biology).[24]
- Numerous new products and processes with currently unknowable implications, risks, and benefits are likely to emerge from the fusion of biology with engineering.

Unlike more traditional ELSI approaches which tend to treat knowledge and practices as fixed, requiring oversight and restrictions administered by independent but possibly antagonistic 'outside' actors,[25] the report suggests that there needs to be a re-conceptualisation of the notion of governance to one where it is seen as a flexible and responsive 'art' (involving multiple points of collaboration), not an imposition. The report singles out iGEM as one of the more important sites for the 'social engineering' of the future synthetic biology scientist.

> iGEM functions as a global hub for young scientists to meet and compete (...) Undergraduate performances at iGEM contests have been treated as important indicators to assess, reflect on, and criticise national policy making. Meanwhile it generates debate about what can/should count as good 'human practices' and also facilitates global exchange and dissemination of concerns over biosafety, biosecurity, IP regimes, ethics and public engagement in the field of synthetic biology. (...) [I]n 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. (...) [D]espite being essentially a 'scientific' competition, iGEM plays a crucial role in the 'social' engineering of the upcoming generation of young scientists.(...) [F]ew policy analyses nowadays would ignore the central role iGEM has over the formation of international research culture in this emerging area.[26]

iGEM, of course, only constitutes one of the many arenas where the identity of the field of synthetic biology is currently being negotiated. For example, there are mainstream professional scientific practices where chemists, biologists, and computer engineers are initiating various new interdisciplinary projects in traditional institutional settings; DIYbio which is far more experimental and speculative, both socially and epistemologically; and the

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23 Ibid 46, 157.

24 I will use the term DIYbio to cover Hacker Biology, Garage Biology, Hackerspaces, Amateur Biology etc.

25 M W Douglas and Dirk Stemerding, 'Challenges for the European Governance of Synthetic Biology for Human Health' (2014) 10 *Life Sciences, Society and Policy* 6 <http://www.lsspjournal.com/content/pdf/s40504-014-0006-7.pdf>.

26 Bios Report, above n 7, 26-27.

entrepreneurial ventures of 'hyper-experts' such as J Craig Venter.[27] iGEM is still, nevertheless, a valuable site because it sits at a junction between these other areas, involving multiple sub-cultures aside from its primarily student participants. It also represents a community that is novel and growing rapidly, and its practices are relatively transparent and have been subject to a number of ethnographic studies. By comparison, for example, DIYbio is still extremely unsettled and in its relative infancy,[28] and specialises in professional practices from a sociological perspective in a way that is not always transparent.[29]

III NORMS AND SOCIAL ENGINEERING

If future generations of synthetic biology scientists are to be 'socially engineered' to become 'responsible stewards', one of the main vehicles for this will be through the development of various norms or dispositions, or habits of thought and practice that are reinforced by the emerging synthetic biology community. Norms operate at a deeper level than regulation and rules, although for rules and regulations to be effective, a normative ethos should ideally re-enforce them by shaping expectations of appropriate behaviour in a community. Norms influence how individuals interact with each other in a community and their self-identification with that community, and how they perceive the relationship of that community with broader society. The fact that norms are in a sense tacit, and do not need to be simply codified, means that they are more likely to become topics of formal discussion when a community is reflecting on its practices, and such reflections are visible to those outside the community. These types of reflections generally become more intense during a crisis or controversy, when a new community is emerging, when there are perceptions that various individuals may be deviating from acceptable standards of behaviour, and in the induction of neophytes into a community. Norms can be analysed both in terms of the behaviour that is deemed desirable, and that which is actually typical and observable, as well as the way a community manages the relationship between these two dimensions.[30]

A *Revisiting Merton's Normative Ethos of Science*

The most influential attempt to explore the idea of norms in *the specific context of the development of scientific and technical communities* is Robert Merton's so-called norms of science.[31] The Mertonian image of science continues to underpin much public, media, and legal discourses surrounding science policy, especially in controversial settings where questions of the ethics of science are often measured against ideal models of conduct.[32]

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[27] Alessandro Delfanti, '"What Dr Venter Did on his Holidays": Exploration, Hacking, Entrepreneurship in the Narratives of the Sorcerer II Expedition' (2009) 28(4) *New Genetics and Society* 415. For discussion of the concept of the 'hyper-expert' see David Mercer ,'Hyper-experts and the Vertical Integration of Expertise in EMF/RF Litigation' in G Edmond (ed), *Expertise in Regulation and Law* (Ashgate, 2004) 85.

[28] Daniel Grushkin, Todd Kuiken and P Millet, 'Seven Myths & Realities about Do-It-Yourself Biology' (Report, Wilson Centre: Synthetic Biology Project, November 2013) <http://www.synbioproject.org/process/assets/files/6673/_draft/7_myths_final.pdf>.

[29] Rabinow and Bennett, above n 14, 171–2.

[30] Melisa S Anderson et al, 'Extending the Mertonian Norms: Scientists' Subscription to Norms of Research' (2010) 81(3) *Research Journal of Higher Education* 366.

[31] Robert K Merton, 'The Normative Structure of Science', in Robert K Merton, *The Sociology of Science: Theoretical and Empirical Investigations* (University of Chicago Press, 1942) 221.

[32] David R Benson and Roger K Kjelgren, *Tacit Diplomacy in Life Sciences: A Foundation for Science Diplomacy* (31 January 2014) Science & Diplomacy <http://www.sciencediplomacy.org/perspective/2014/tacit-diplomacy-in-life-sciences>; Alison Mclennan, 'Building with BioBricks: Constructing a Commons for Synthetic Biology Research', in Mathew Rimmer and Alison Mclennan (eds), *Intellectual Property and Emerging Technologies: The New Biology* (Edward Elgar, 2012) 176; Henry Etzkowitz and Andrew Webster 'Science as Intellectual Property' in S Jasanoff et al (eds), *Handbook of Science and Technology Studies* (Sage, 1995) 488; Sheldon Krimsky, 'Science, Society and the Expanding Boundaries of Moral Discourse' in Kostas Garroglu et al (eds), *Science Politics and Social Practice: Essays on Marxism, Science, Philosophy of Culture and the Social Sciences* (Routledge, 1995) 113.

Mertonian ideals in various forms also appear in the commentaries of proponents of open source cultures including iGEM and DIYbio.[33] Whilst Merton's norms have been subject to considerable critique within the field of Science and Technology Studies (STS) (more on this below), their underlying resonance in popular discourse about science makes them a useful heuristic. They assist in considering not only what sort of normative ethos may, or may not, be emerging from iGEM, but also how participants and commentators frame their descriptions and aspirations for such an ethos, and what may be some of the limits of attempting to build such a 'normative ethos' to start with.

The special character of the Mertonian norms are strongly underpinned by assumptions about what sort of standards of conduct are necessary for independent knowledge-making communities to emerge, progress, and be sustained. Consistent with objectivist philosophies of science and their Popperian variations, Merton believed in the unique cognitive and social authority of modern science.[34] This meant part of his sociological project was to help distinguish what made the social system of science unique, but also to identify features of that system that were exemplary for communities seeking to produce authoritative knowledge more generally. Merton derived his norms not from statistical quantitative or empirical analysis, but rather from his prior work in the history of the emergence of modern science, a wealth of anecdotal evidence, and his philosophical assumptions about the nature of science noted above. Merton believed that the very broad norms he identified were universally recognised by scientists as essential to the continuing health and progress of science. Merton noted that despite occasional non-conformity, the norms still provided, in a sense, the backbone for the survival of the ongoing social structure of science. Merton's well-known formulation was based on four interlocking norms:

- *Communalism*: Scientific work and findings should be shared.
- *Universalism*: The results of scientific work should not be interpreted on the basis of who is producing it (status and gender of the researcher for example).
- *Disinterestedness*: Scientists should avoid having too much of a personal stake in their knowledge, and their aims are ultimately to progress knowledge ahead of all else.
- *Organised Scepticism*: Scientific work should have a system of criticism embodied in practices such as peer review.

Merton was aware that things like the status afforded to scientists regarding novelty and discovery encouraged them to take a personal stake in, and adopt emotional commitment to, their work. But he suggested that these motivations for acknowledgement of priority, and rewards of eponymy, were still overwhelmed by the broader ethos that knowledge should be progressed beyond these motivations, and that various norms he identified were central to the spirit of science.[35]

The neatness of Merton's system has frequently been challenged by empirical work in the sociology of science, most notably that of Ivan Mitroff. Mitroff identified in his research that, depending on the context, scientists also interpreted counter-norms to be essential for science to operate: solitariness, particularism, interestedness and organised dogmatism. These are polar opposites to Merton's 'positive' norms. Accepting the existence of counter-norms compromises the neatness of the Mertonian system. If we accept Mitroff's and other

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[33] Alessandro Delfanti, 'Hacking Genomes: The Ethics of Open and Rebel Biology' (2011) 15 *International Review of Information Ethics* 53.

[34] R Albury, *The Politics of Objectivity* (Deakin University Press, 1983); D Hess, *Science Studies: An Advanced Introduction* (New York University Press, 1997).

[35] Robert K Merton, 'A Note on Science and Democracy' (1942) 1 *Journal of Legal and Political Sociology* 115.

critiques, we now have at best an expression of preferred norms, not always conformed to in all contexts of scientific work.[36]

Building on these critiques, Michael Mulkay provided a highly influential and persuasive reconceptualisation of what Merton's system seemed to 'actually' be describing.[37] Mulkay pointed out that there was a paucity of evidence that Merton's norms were, or have ever actually been, systematically institutionally reinforced, or that conformity to them was rewarded, or non-conformity punished. At the same time, reference to the types of norms identified by Merton is, or was, still common in popular discourse about science, and they are frequently used by scientists themselves to describe their communities. Mulkay suggested that this meant that the norms are better explained as one of the broader public cultural stereotypes about how, in an ideal world, scientific communities should work, and are drawn upon as part of the professional boundary working rhetoric of scientists.[38] The promotion of this idea, that science has a special normative ethos, has historically assisted scientists in building the trust and authority they require to assert functional autonomy over how they do their research and spend the funds of their sponsors. Mulkay suggests that if we are to understand the behaviour of scientists it will be through a sociologically informed contextual analysis. Neither institutional structures nor the epistemological fabric of science bind scientists in any kind of straightforward way, and an overarching normative structure for science does not exist other than as a feature of scientists' discourse and discourse about science.[39]

The Mertonian traditions of identifying unique scientific norms, then, are part of the ideology of science, normally serving as a form of promotional rhetoric, but also a source of ambivalence when difficulties are encountered in applying norms to practice. Studies of sociological ambivalence have been preoccupied with ways individuals maintain and manage contradictory beliefs. Merton helped develop sociological interpretations of ambivalence in part as an attempt to explain counter-norms in science. He believed that ambivalence was most likely to arise when actors occupied multiple statuses with conflicting expectations and abilities to fulfil their aspirations.[40] Studies of scientists have noted displays of sociological ambivalence involved in the tensions between managing questions of intrinsic versus instrumental value of work, independence versus dependency, and collegial versus legal rational modes of authority.[41] Given the multiple competing roles and ambiguities in status involved in iGEM, which involves the interactions of students from different academic disciplines, participant observers, and entrepreneurial visible scientists, it is an obvious arena where questions of sociological ambivalence could be expected to arise.

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36 Ivan Mitroff, 'Norms and Counter Norms in a Select Group of the Apollo Moon Scientists' (1974) 39 *American Sociological Review* 579; Barry S Barnes and Robert G Dolby, 'The Scientific Ethos: A Deviant Viewpoint' (1970) 11 *European Journal of Sociology* 3.

37 Michael Mulkay, 'Norms and Ideology in Science' (1976) 15 *Social Science Information* 637.

38 Thomas Gieryn, 'Boundary Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists' (1983) 48 *American Sociological Review* 781.

39 Other commentators have suggested perhaps a looser, more up to date formulation of norms may still be a useful conceptual tool, adding new norms to Merton's that capture some of the changes to the way current sciences are practiced: Anderson et al, above n 30. These attempts tend to gloss over one element of Mulkay's critique (following Wittgenstein), that the contexts in which norms (like rules) are meant to operate will always offer challenges beyond the norms that are identifiable, which could lead to ongoing multiplication of norms, which can in turn limit the value of the exercise to start with: Michael Mulkay, 'Interpretation and the Uses of Rules: The Case of the Norms of Science' in T Gieryn (ed), *Science and Social Structure: A Festschrift for Robert Merton*, (New York Academy of the Sciences, 1980) 111.

40 Michael Carolan, 'Sociological Ambivalence and Climate Change' 15 (2010) *Local Environment* 309.

41 Michael Arribus-Ayllon and Andrew Bartlett, (2013) 'Sociological Ambivalence and the Order of Scientific Knowledge' *Sociology* 1; Edward J. Hackett (2005) 'Essential Tensions: Identity, Control and Risk in Research' (2005) 35 *Social Studies of Science* (5) 787.

In further discussion below (Section V) Mulkay's critical interpretation of the Mertonian tradition will be taken as a point of departure to analyse claims that iGEM practices will help shape the development of an ideal synthetic biology normative ethos. Before doing this, the reader needs to be provided with some background about the emergence and growth of iGEM.

IV iGEM: BIOBRICKS, 'GIVING AND GETTING'

> Our mission is to ensure that the engineering of biology is conducted in an open and ethical manner to benefit all people and the planet. We envision a world in which scientists and engineers work together using freely available standardized biological parts that are safe, ethical and cost effective and publicly accessible to create solutions to the problems facing humanity.[42]

It is important to note from the outset that iGEM is most strongly linked to a 'computer engineering vision' or 'sociotechnical imaginary' for the future of synthetic biology. The idea of 'sociotechnical imaginaries' has been developed by Sheila Jasanoff (and others) to capture the way narratives about the future prospects of various scientific and technical paths also embody various broader social visions, expectations, and histories.[43] The 'computer engineering vision' is exemplified in the work of Drew Endy.[44] Other visions for the future of the field also exist, the most notable alternative being that of Steven Benner and A Michael Sismour, of synthetic biology as 'a biologically inspired extension of chemistry'.[45] Historian and philosopher of science Bernadette Bensuade Vincent explains that the computer engineering vision aims to re-orientate biology towards engineering by involving standardisation, decoupling of parts, abstraction, quantification, simplification, recognition of innovation in informal settings, prediction and control, responsibility and self-regulation and open IP regimes. In contrast, the biological extension of the chemistry model emphasises continuities with work over the last 20 years in organic synthesis, and biology more generally. This includes the need to follow traditional approaches to patenting and IP with a mixture of academic research, practical developments, commercial profits, and regulation, recognising that results may not be completely predictable. Bensaude Vincent's observations about the unsettled nature of the emerging disciplinary identity discourses in synthetic biology highlight that care needs to be taken in treating iGEM as a vehicle for the development of a normative ethos for the whole field of synthetic biology.

As a way to expand on the month-long short courses they had started offering at Massachusetts Institute of Technology (MIT), synthetic biology pioneers Drew Endy, Tom Knight, Randy Rettberger, and others, decided to start a competition for students to do synthetic biology projects. They drew inspiration from various student engineering

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[42] The BioBricks Foundation, *About* (2015) <http://biobricks.org/about-foundation/>.

[43] Harvard Kennedy School, *STS Research Platform – Sociotechnical Imaginaries* (2012) <http://sts.hks.harvard.edu/research/platforms/imaginaries>; Nuffield Council on Bioethics, *Emerging Biotechnologies: Technology Choice and the Public Good* (2012) <http://nuffieldbioethics.org/project/emerging-biotechnologies/>.

[44] Drew Endy, 'Foundations for Engineering Biology' (2005) 438(25) *Nature* 449.

[45] Bernadette Bensaude Vincent, 'Discipline Building in Synthetic Biology' (2013) 44 *Studies in History and Philosophy of Biological and Biomedical Sciences* 122 <https://hal-paris1.archives-overtes.fr/hoal-00931814>; see also Susan Molyneux-Hodgson and Morgan Meyer; 'Tales of Emergence a Scientific Community in the Making'(2009) 4 *Biosocieties* 2; Drew Endy, 'Foundations for Engineering Biology' (2005) 438(25) *Nature* 449; Steven Benner and Alan Sismour, 'Synthetic Biology' (2005) 6 *Nature Reviews Genetics* 533. It should also be noted that there are also more radical DIYbio visions working beyond traditional concepts of academic or scientific communities. See Denisa Kera, 'Innovation Regimes Based on Collaborative and Global Tinkering: Synthetic Biology and Nanotechnology in the Hackerspaces' (2014) 37 *Technology in Society* 28. The relationship between DIYbio, iGEM, and the computer engineering visions of Endy will be commented on later in Section V D. It is also interesting to note, in this unsettled context of discipline building that J Craig Venter prefers the term synthetic genomics to synthetic biology.

competitions, particularly the FIRST (For Inspiration and Recognition of Science and Technology) robotics competition.[46] Complimentary to these relatively straightforward aims of promoting education in synthetic biology was the promotion of their concept of BioBricks. Endy and his colleagues believed that time and costs could be reduced for doing synthetic biology research if a standard for biological parts, and a registry of standardised parts to allow for their share and re-use, was created. A student competition linked to promoting the BioBricks concept could provide a stimulus for its faster growth. With help from the US National Science Foundation, they expanded their vision into the International Genetically Engineered Machine (iGEM) competition. The first competition was held in 2004 involving only a handful of US Universities (Caltech, MIT, Princeton and the University of Texas, Austin). It was held annually at MIT until 2012 and has moved more recently to a nearby venue administered by the BioBricks Foundation (BBF), now an independent non-profit organisation.[47] iGEM is possibly the largest single synthetic biology event in the world with 2,300 people attending its final function in 2014. iGEM has grown so much that 245 teams competed in 2014 with various regional divisions and a growing variety of prizes and judging categories.[48]

iGEM caters mainly for undergraduate university students, although recently there has been expansion in some areas for broader age groups to participate, such as high school divisions. Teams are still nevertheless highly reliant on academic supervisors, mentors and significant institutional support. Teams are interdisciplinary with students from backgrounds in computer science, engineering, and biology, and even budding artists and social scientists. So far, however, biologists, followed by engineers and computer scientists, have tended to form the nucleus, and drivers, of the teams.[49] There has also been some history of informal links between teams and amateur and DIY biologists, but organisers have generally been reluctant to allow such groups formal entry into the competition.[50]

The teams are asked to define a specific social or technical problem, or goal or purpose, then design and build what Endy has described as a 'DNA program' to solve it. The 'DNA program' must be designed and built according to certain rules and protocols, including safety and social implications. This also has to be done within a relatively tight time frame, during the three months of the northern hemisphere summer. Perhaps most importantly, the 'DNA program' must be built by drawing from standardised biological parts that are made available from the BioBrick repository. From 2008, projects could also include a Human Practices (now just Practices) dimension, demonstrating that the team had engaged with what could loosely be described as the social ethical aspects of their project. The majority of teams now incorporate this dimension into their projects.[51] I will return to discuss Human Practices in more depth at a later point.

The competition builds on the vision of facilitating biology to become an engineering discipline by building simple biological systems from standard interchangeable parts. Various metaphors from engineering and computing ('chassis' and 'wetware') blend with 'cool' images of adventure and play ('Lego blocks' and cartoon instructional magazines), and knowledge sharing ('freeware' and 'getting and giving').[52]

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46 Christina D Smolke, 'Building Outside the Box: iGEM and the BioBricks Foundation' (2009) 27 *Nature Biotechnology* 1099.

47 The BioBricks Foundation, *About* (2015) <http://biobricks.org/about-foundation/>.

48 iGEM, *About* (2015) <http://igem.org/About>.

49 Emma Frow and Jane Calvert, above, n 15; Andrew Balmer and Kate Bulpin, above n 15.

50 Sara Aguiton, *SynthEthics: An Ethical and Sociological Analysis on Synthetic Biology*, (2009) iGEM 2009 <http://2009.igem.org/wiki/images/archive/b/b2/20091021203514!TeamParis-SynthEthics.pdf> 38.

51 Frow and Calvert, above n 15, 53.

52 Alan Liu, *The Laws of Cool: Knowledge Work and the Culture of Information* (Chicago University Press, 2004); Surfdaddy Orca, *Adventures in Synthetic Biology: An Interview with Stanford's Drew Endy* (2009) H+Magazine <http://hplusmagazine.com/digitaledition/2009-winter/>.

At the beginning of each competition students are sent a kit of genetic parts (getting), and at the end of the competition the teams contribute (giving) their designs back to the BioBrick repository for future use in iGEM competitions, and for use by the wider synthetic biology community. Projects are judged by a panel of scientists, biotech industry and government figures, and academics from a variety of disciplines. Medals are awarded (bronze, silver, and gold) based on the assessment of posters, oral presentations, and quality of wiki pages. There is also a Human Practices prize and the *Grand BioBrick Trophy* awarded for the best project.[53]

In the decade or so iGEM has operated, it can claim a number of achievements, which include:

- The continued growth of the BioBrick repository.[54]
- The successful development of iGEM projects in fields like bio-sensing and medical diagnostics, and projects leading to a number of external grants, patents, and prestigious publications.[55]
- Ex iGEMers contributing to the development of synthetic biology start-up companies, most notably Ginkgo Bioworks.[56]
- A number of ex iGEMers figuring prominently in the emerging DIYbio movement.[57]
- More intangibly, the competition has also captured the imaginations of students, universities, media, and policy makers, and has been an important tool for publicising the idea of synthetic biology.

V NORMS AND IDEOLOGY IN IGEM

As noted in my introduction, the iGEM competition is seen by many commentators as one of the most distinctive and important features of the emerging field of synthetic biology, particularly for the development of shared norms. Frow and Calvert note: 'iGEM has proven to be important in many respects. It has been a key vehicle for training and community formation in synthetic biology, enrolling students, advisors, and laboratories across the globe into a common project with shared norms.'[58]

Stavrianakis, another post-ELSI ethnographer of iGEM, re-enforces the theme:

> Whilst, as we will see, the question of what is made through synthetic biology varies, its practices, ends and achievements depend on different conceptualizations of biological problems, specific techniques and technologies, the question of *who a* synthetic biologist is, was at this time, to a large degree, controlled by passing through the pedagogical experience of iGEM. This experience and self-designation of a subject's position, whilst not determinative of a 'field' was constitutive of an ethos toward a practice of science and engineering.[59]

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53 Smolke, above n 46, 1100.
54 Bryn Nelson, 'Cultural Divide' (2014) 509 *Nature* 152.
55 Smolke, above n 46, 1102.
56 Nelson, above n 54,154.
57 Catherine Jefferson, 'Governing Amateur Biology: Extending Responsible Research and Innovation in Synthetic Biology to New Actors – Research Report for the Wellcome Trust Project on "Building a Sustainable Capacity in Dual-Use Bioethics"' (Report, Wellcome Trust Project, 2013) <http://www.brad.ac.uk/bioethics/media/ssis/bioethics/docs/Jefferson_Governing_Amateur_Biology.pdf>.
58 Frow and Calvert, above n 15, 44.
59 Anthony Stavrianakis, *Flourishing and Discordance: On Two Modes of Human Engagement with Synthetic Biology* (PhD Dissertation, University of California, Berkeley, 2012) 121–2 <http://escholarship.org/uc/item/2b50r68z?query=Flourishing%20and%20Discordance:%20On%20Two%20Modes%20of%20Human%20Engagement%20with%20Synthetic%20Biology> (emphasis in original); Adrian Mackenzie, 'Design in Synthetic Biology' (2009) 5(2) *Biosocieties* 180.

Similar to some of the promotional rhetoric associated with DIYbio, iGEM has been lauded as one of the places where Mertonian and neo-Mertonian norms of communalism and universalism, which have arguably been compromised by excessive corporate and government interference in science, can be significantly revived. Why I suggest 'neo-Mertonian' norms is that the celebration of these traditional Mertonian normative values is also often coupled with the idea that iGEM and DIYbio are also promoting an updated ethos for synthetic biology. This allows for more individualism, experimentation with modes of practice, and diverse input into knowledge creation and authorisation, than traditionally imagined. This fosters a situation enhanced by new venues for doing science and for communicating results. Alessandro Delfanti describes these possibilities in terms of a Mertonian re-mix.[60]

In a sense, many of the ideal norms of iGEM do intersect quite well with aspects of a Mertonian or a neo-Mertonian image of the ideal ethos of science. For example:

- *Communalism* resonates strongly with ideals of free-ware, team wikis, giving back to the BioBrick repository and not seeking IP.
- *Universalism* appears in the wide breadth of international representation, lack of concern with status and qualifications of participants, and interdisciplinarity and collaboration – the project is more important than the promotion of any traditional disciplinary identity.
- *Disinterestedness* is exemplified in the two behaviours promoted above of sharing and aversion to IP, interdisciplinary team orientation, and in the values of promoting synthetic biology for broader human benefit ahead of individual benefit.
- *Organised Scepticism* is promoted in the processes of transparent judging of projects and awarding of prizes.

Whilst iGEM's ideal values do seem to have some congruence with Mertonian and neo-Mertonian visions, on a deeper inspection (which I will expand on below) it appears that for the competition to be sustained in practice these values operate in tandem with competing values.

There are a number of contextual features of iGEM that create challenges to sustaining its ideal norms. These can be listed under four overlapping rubrics:

- Intellectual freedom in a competition with structured rules.
- Interdisciplinarity where various disciplines are more central than others.
- Upstream reflexive ethical engagement in a culture where such concerns are routinely back-staged.
- Sharing and communalism in a context that is highly competitive and where IP laws in practice are much more complex than competitors envision them to be.

In the analysis that follows, I will expand on these rubrics drawing mainly from various post-ELSI 'ethnographic' accounts of participant observers (collaborators), who assisted iGEM teams in their preparations, visited jamborees, and functioned as judges, mentors, or informal advisors. This includes the work of Calvert and Frow, Stavrianakis, Balmer and Bulpin, and Cockerton.[61] Due to the nature of the competition, there are also a variety of on-line materials linked to team wikis and, where appropriate, these will also be drawn on.

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[60] Delfanti, above n 33.

[61] Caitlin Cockerton, 'Going Synthetic: How Scientists and Engineers Imagine and Build a New Biology' (PhD Thesis, London School of Economics and Political Science, 2011); Balmer and Bulpin, above n 15; Stavrianakis, above n 59; Frow and Calvert, above n 15.

Relying extensively on the analysis and interpretations provided by social science researchers engaged in 'collaborative' styled research raises some interesting methodological issues which are worthy of being flagged, although they are beyond the scope of the current paper to essay at length. The idea of collaborative research creates some interesting challenges to more traditional conceptions of the importance of maintaining critical analytical distance from the subjects of research. As noted above many of the accounts I will draw upon are from analysts who performed multiple roles in iGEM as members of multiple sub-communities. For example, researchers acted as honorary members of teacher/student communities as iGEM mentors; honorary members of the synthetic biology professional community as iGEM judges; and members of social science and social policy communities as commentators and publishers of reports and academic papers. Satisfying such multifaceted roles, and juggling sometimes competing social interests, invites questions about whether their accounts of iGEM's strengths and weaknesses might be inclined to display some sociological ambivalence. I will leave this question to the reader's judgment.

In identifying what I believe are tensions in iGEM's norms, my own position is not as a critic of iGEM per se (the literature suggests that students enjoy and personally benefit from the iGEM experience), but rather to offer an exercise in bringing to the foreground aspects of the culture of iGEM which tend to be overlooked in most accounts, which never go beyond extolling iGEM's virtues. I should also note that iGEM is something of a moving target with the capacity for rules to be modified within reasonably short time frames and in response to critics.

A *Intellectual Freedom and Universalism in a Competition with Structured Rules*

It is no secret that iGEM encourages a strong competitive spirit. Drew Endy describes it as 'akin to a genetic engineering Olympics for undergraduates.'[62] Balmer and Bulpin, and Cockerton, note the personal tensions, fear of failure, and joy of success students experience in their chase for medals, especially gold. They also note the pressures of strong expectations held by, and the superior resources and dominant success rates of, elite institutions, and the unabashed promotion of a meritocratic discourse that rather mythically implies all teams are competing on a level playing field.[63] The potentially narrow focus of a 'medal chase' co-exists in potential tension with other stated iGEM values – to be supportive of smaller institutions and amateur biology, and for projects to reflect on their social implications and be geared towards broader social benefit.[64]

Balmer and Bulpin also note that the highly structured nature of the competition creates time pressures which discourage certain projects being attempted, and continuously attenuates the capacity for participants to learn new skills and engage in interdisciplinarity and, in particular, to address the Human Practices (Practices) dimensions of their projects.[65]

> [T]here is a major constraint on human practices work in iGEM. You have very little time to read or explore HP [Human Practices] scholarship, and – for the most part – having only studied a single subject at university, most of you will be unfamiliar with the methods and conceptual apparatus used in humanities and social sciences ... After all, there's no hope of a medal or an award if you haven't actually got an engineered microbe

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[62] Drew Endy, *Effects of Developments in Synthetic Genomics – Hearing before the Committee on Energy and Commerce* (27 May 2010) US House of Representatives – Democrats: Committee on Energy and Commerce <http://democrats.energycommerce.house.gov/sites/default/files/documents/Final-Transcript-FC-Developments-Synthetic-Genomics-2010-5-27.pdf>.

[63] Balmer and Bulpin, above n 15. It should be noted that Merton was aware of elitism in science or the so-called 'Mathew Effect': Albury, above n 34.

[64] Cockerton, above n 61.

[65] Balmer and Bulpin, above n 15.

> to present no matter how many people you've talked to about your project or how much you've learned about social science. So the priorities of iGEM teams are set-up in part by the medal criteria.[66]

The structured nature of the IGEM competition also places pressure on the kinds of projects teams choose in more 'technical' ways. Organisers insist on teams using the appropriate parts that are supplied to them, and that can be given back to the BioBrick repository. Teams that do not generate standardised parts do not win prizes, even if the quality of their work is exceptional. Frow and Calvert advert to tensions that teams experience in trying to get their work to fit the rules, and to judges who may face difficulties in adjudicating between projects with significant biological merit relative to projects that better fit the criteria of contributing to the BioBrick registry.[67] This suggests that whilst the existence of standardised rules can encourage communalism and sharing, it can also potentially compromise ideals of organised scepticism. For example, it may not be the project with the best science that wins a prize, or the most interesting project that a team would want to do, but one that they can do with the pre-approved materials that best fit the criteria of supporting the vision of developing the BioBrick repository. Chasing the competition criteria, ahead of more general scientific criteria, has extended at times to projects using the iGEM BioBrick approaches to solving problems that already have solutions using non-synthetic biology approaches.[68]

B *Interdisciplinarity where Various Disciplines are More Central than Others*

Frow and Calvert, Balmer and Bulpin, and Stavrianakis have all noted that iGEM teams often experience tensions in reconciling the roles to be played in projects of different students from different disciplines, and how these roles and contributions come to be described in final projects. This again can be seen as a drift away from values of universalism and organised scepticism. In many cases, biology students, for example, provide the greatest input at the 'hands on' messy laboratory end of projects, whereas other students, engineering and IT for example, put more effort into modelling, design, and packaging the project into a coherent polished form for final judging. So the pressures to conform to iGEM's positive innovation rhetoric, and to be viable in competition, can mean the nature of the work done by the team, and the relative contributions of team members, can come to be misrepresented. The engineering and innovation possibilities of a project may be highlighted ahead of adequate descriptions being provided of the messier laboratory work that has actually been done.[69]

Another challenge faced by iGEM in maintaining an inclusive, universalistic ethos surrounds its relationship with DIYbio. In many places, commentators have noted the ethos of iGEM dovetails with DIYbio.[70] For example there have been a number of important players in the DIYbio movement who started in iGEM, and iGEM projects that have had links with DIYbio.[71] Nevertheless, there are other points where the relationship has faced challenges. Most notably, in 2009 a DIYbio team applied for entry into the competition but was refused by iGEM organisers on a number of grounds, including lack of insurance and institutional oversight.[72] Whilst the organisers of iGEM have regularly appeared in public contexts supporting DIYbio, some DIYbio supporters have voiced concerns that the BioBricks initiative's links to business interests are not consistent with the true spirit of DIYbio.[73]

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66 Andy Balmer, *Public Perceptions, Knowledge Deficit and Expertise* (4 September 2014) Reasonable Excuse <https://andybalmer.wordpress.com>.
67 Frow and Calvert, above n 15, 49.
68 Cockerton, above n 61, 15, 37.
69 Frow and Calvert, above n 15, 50.
70 Kera, above n 45; Aguiton, above n 50.
71 Jefferson, above n 57, 13.
72 Aguiton, above n 50, 38.
73 Stavrianakis, above n 59, 135–6.

Cockerton also notes a case where tensions have (in a sense) flowed the other way, where some iGEM participants expressed the view that some DIY biologists attending various iGEM functions were not completely conforming to DIYbio ideals.[74] Many of these DIY biologists had full time institutional appointments and qualifications alongside their DIYbio interests, and appeared more interested in getting inspiration from iGEM for commercial start-up opportunities than building community projects.[75]

The dominance of various academic disciplinary perspectives, and the tensions that flow from this, have also been reported on in the way teams have dealt with the Human Practices components of projects. Stavrianakis recounts the example of an anthropology student he was mentoring, part of an iGEM team from University of California, Berkeley, being 'told not to introduce herself [to the judges] as an anthropologist, on the grounds that "people won't understand and it will be a distraction."'[76] She was also told to only focus on narrow parts of her research which directly involved the technical steps that would be involved in patenting processes directly related to the team project, and avoid the wider theoretical discussion of the broader issues relating to open source and patenting in iGEM, which she had prepared. Stavrianakis noted that even this significantly sociologically diminished presentation elicited a response from a senior synthetic biologist from a world leading university who commented: 'Why are you talking about patents? iGEM is supposed to be about fun. It's meant to be a fun summer thing. I don't think this gives the right impression, all this talk about patents, that shouldn't be your concern.'[77]

This point overlaps with the discussion in the next section, and also reiterates points noted above, about how easy in practice it is for iGEM to fulfil strong universal and interdisciplinary aspirations when it is set up as a competition with strict rules, time frames, and a strong underlying focus to promote (to use Bensuade Vincent's term) a computer engineering imaginary for synthetic biology.

C *Upstream Reflexive Ethical Engagement in a Culture where Such Social Concerns are Routinely Backstaged*

As noted earlier, in 2008 iGEM introduced the option for teams to incorporate a so-called 'Human Practices' component into their project. The term Human Practices was coined by anthropologist Paul Rabinow, who initiated one of the first experiments in social science upstream engagement in synthetic biology, in the synBERC project centred on the University of California, Berkeley. Rabinow envisaged Human Practices as a radical alternative to traditional ELSI approaches to governance of synthetic biology. The approach offers an exemplary model of a policy strategy based on the idea of developing a new normative ethos amongst synthetic biology scientists. A key element of Human Practices was for social scientists, through various processes of evaluation, facilitation, engagement, and collaboration, to encourage synthetic biology scientists to become highly reflective about their practices (these processes are described under the heading of pedagogy). It would be out of this collaboration and reflection that the new ethos for practising the discipline of synthetic biology would emerge. It is through consideration of how their practices enhance 'the good life' that scientists and engineers (and human scientists) are enabled to 'flourish'. Rabinow identified the goals of Human Practices as bringing:

> [t]he biosciences and the human sciences into a mutually collaborative and enriching relationship, a relationship designed to facilitate a remediation of the currently existing relations between knowledge and care in terms of mutual flourishing. If successful, such

[74] Cockerton, above n 61, 269-270.
[75] Ibid.
[76] Stavrianakis, above n 59,135.
[77] Ibid 134–5.

> practices should facilitate our current work in synthetic biology – understood as a Human Practices undertaking – through improved pedagogy and the invention of collaborative means of response.[78]

Some important themes that one would expect to be exported from Human Practices into iGEM include things like: considering users in design; incorporating insights from collaborations with non-scientists into the early phases of design and project objectives; and ongoing serious engagement with ethical and epistemological questions raised by the mutual learning taking place between scientist and non-scientist collaborators.[79] These preoccupations could be expected to be set against the avoidance of so-called literary deficit models towards the public understanding of science, that is, that public ignorance is the key factor explaining negative public views about new science.[80]

Frow and Calvert, Cokerton, Stavrianakis, and Balmer and Bulpin, have all noted that these visions for 'Human Practices' have been far from realised in the vast majority of projects. Rather than the ideal of developing ethical and social awareness (reflexivity) in budding synthetic biologists by having 'social' concerns integrated into the fabric of projects from the outset, Human Practice components tend to have become exercises that run parallel or behind the main project, with little integration into the content of the project, and with greater preoccupations with synthetic biology public relations than ethical reflection. Performing surveys of public attitudes towards synthetic biology, framed by assumptions about public ignorance, and thinking of ways to increase public awareness of the benefits of a synthetic biology future (and variations on this theme), would appear to have become standard approaches to dealing with 'Human Practices' in most projects. Andrew Balmer, who was involved as a social scientist ethnographer and mentor in iGEM, describes the way most iGEM teams retreat from more serious ethical and sociological engagements:

> A related idea was that this 'public ignorance' of the science could be somehow cured if we educated people about GM technologies. In this regard, scientists assumed the main problem was a 'knowledge deficit' in public understanding of science, which meant that public perceptions of science were skewed and inappropriate but could be changed by better education and 'outreach'. So scientists set about telling people about the GM work they were doing, hoping to calm 'the public' fears by providing knowledge. In iGEM much of the work that teams do in human practices still follows this model. Most teams go out into public spaces like schools, community centres and so forth, to tell people about the work they're doing. Mostly it is a one way thing, where teams tell people the science and hope that this interests them or at least that it allays some of their fears.[81]

Frow and Calvert acknowledge the trajectory identified by Balmer, but retain their optimism by suggesting that iGEM judges are working to overcome it:

> But there is a growing tendency for iGEM judges to reward those teams who embrace the spirit of heterogeneous engineering and incorporate an understanding of social, political, economic and human factors into the details of their technical projects ... A flexible space for interaction between ELSI and engineering ethics work may be starting to open up

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[78] Paul Rabinow, 'Prosperity, Amelioration, Flourishing: From a Logic of Practical Judgment to Reconstruction' (2009) 21(3) *Law and Literature* 305. It is interesting to note that the Human Practices experiment more generally has been beset with difficulties in being applied in practice. See also Gary Edmond and David Mercer, 'Norms and Irony in the Biosciences: Ameliorating Critique in Synthetic Biology' (2009) 21(3) *Law and Literature* 445; David Caudill, 'Synthetic Science: A Response to Rabinow' (2009) 21(3) *Law Literature* 431; Rabinow and Bennet, above n 14.

[79] Jane Calvert and Paul Martin, 'The Role of Social Scientists in Synthetic Biology: Science and Society Series on Convergent Research' (2009) 10(3) *EMBO Reports* 201.

[80] B Wynne, 'Public Understanding of Science' in S Jasanoff et al (eds), *Handbook of Science and Technology Studies* (Sage, 1995), 361, 361–88.

[81] Balmer, above n 66.

> through the iGEM competition, in response to demands for training a new generation of reflexive bioengineers.[82]

So the original vision of Human Practices is in some form still promoted as a part of iGEM, but more as a future possibility. There are clear differences and slippages in what the initiative actually means, and how it might influence (if at all) the actual normative and ethical orientation of iGEM participants.

Following Mulkay's more critical reading of Merton's norms as important parts of the rhetoric for scientists to communicate to outsiders, which may have tenuous links with practice, the continued reference back to the novelty of Human Practices in iGEM appears to satisfy a similar role. Fairly mundane engagements with ethical and social issues by iGEM teams, which do not display much sense of them evolving new normative sensitivities, are regularly still rhetorically packaged as part of some kind of important emerging iGEM ethos.

D *Sharing and Communalism in a Context that is Competitive and Where Intellectual Property Laws in Practice Are Much More Complex Than Competitors Envision Them to Be*

One of the most highly visible ideals of iGEM surrounds appeals to the ethos of freeware and open access intellectual property regimes, which appear frequently in more formal statements made about the competition. Aspects of these ideals are embedded within its rules, and are also part of the informal culture of competitors. Frow and Calvert, for example, note: 'When one team announced at a 2009 competition that it had filed three patents as part of its projects, boos were heard in the audience.'[83]

Maintaining an ideal separation between iGEM, corporate, and institutional interests is not easy in practice. Participating in iGEM can be an expensive undertaking requiring considerable institutional support and expenditure on things like lab facilities, airfares, and accommodation. To secure sponsorship, iGEM teams prominently display corporate logos and other promotional advertising for their sponsors on various web sites and T-shirts. Sponsors include the very types of companies benefiting from IP regimes to which iGEM and BioBricks are in theory offering an alternative. Cockerton notes that the dissonance between the more idealistic face of iGEM, and corporate and institutional realities, is also noticeable at iGEM Jamborees. She recounts the conspicuous presence of corporate representatives and, perhaps more jarringly, extremely friendly, armed FBI agents and FBI sponsored talks on bio-security.[84]

Tensions can also run at a deeper level where at numerous points iGEM discourse is also openly entrepreneurial (since 2012 the competition has sported an entrepreneurial division) and aspirations of generating huge wealth from engaging in synthetic biology are widely promoted. Cockerton ironically recounts iGEM organiser Randy Rettberger's advice to iGEMers in a closing ceremony in 2009:

> I think that over the next 40 years synthetic biology will grow in a similar way [as the computer revolution] and become at least as important as the Internet is now and that you will be the leaders, that you will form companies, that you will own the private jets and that you will invite me for rides.[85]

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82 Frow and Calvert, above n 15, 54.
83 Ibid 51.
84 Cockerton, above n 61, 249, 270.
85 Ibid 277.

What is not said is that most of the likely paths to the levels of wealth envisaged above are likely to be dependent on establishing intellectual property rights that are not inevitably, but highly likely to be, in conflict with the open-sharing ethos publicly championed as a feature of iGEM.

Debates surrounding whether a communalistic ethos is consistent with private ownership of knowledge and business success are not new and are unlikely to be easily resolved. For hackers who see seeking wealth as unproblematic, the aphorism that is frequently deployed is 'free speech not free beer' in the sense that freeware is free. For others there is a risk that a hacker or freeware ethos is at best a temporary affectation prior to the co-optation of knowledge to serve business interests.[86] Norms of communalism may apply when one is an iGEM student, but not when one becomes a professional scientist, or creates a start-up company, or an iGEM project offers potential commercial success in the 'outside' world. For iGEM to be an incubator of a normative ethos of communalism it could be expected that the ethos would 'travel' beyond the competition. This may be difficult.[87]

In many respects the tensions experienced by iGEMers in relation to IP philosophies can be seen as a microcosm of issues being negotiated across the field of synthetic biology more generally. A recent commentary in *Nature*, for instance, refers to the two cultures of synthetic biology relative to attitudes they embrace towards intellectual property.[88] In a thoroughgoing analysis of the discourses and practices encouraged by the BioBrick Foundation's approach to intellectual property, Stephen Hilgartner points out that the BioBrick initiative embodies a vision of open source that may deviate considerably from a straightforward defence of open science and public knowledge.[89] He notes that their model strongly privileges the ideal of the creative, innovative User ahead of the Contributor. Whilst Users are encouraged to contribute their creations to the foundation, it does not employ *copyleft* licences on parts (which would restrict future uses) and provides very few restrictions on how Users might wish to use the foundation's materials:

> The regime is designed to allow Users to deploy parts at will, without constraints stemming from availability, fees or propriety restrictions. The User's rights to his or her creations even extend to allowing exit from the restrictions of the regime. If a User invents something of value using BioBricks parts as components, the User may file for patent or otherwise seek property rights in that invention.[90]

Contributors, in contrast, are subject to numerous restrictions on asserting any kind of property rights or licences in relation to their contributions. Hilgartner describes this as a 'leaky regime': 'the regime cannot prevent next generation creations assembled using BioBrick parts escaping its control'.[91] They are at the mercy of Users voluntarily deciding to become Contributors and donate their parts rather than simply patenting and commercialising parts as they see fit.[92] Hilgartner suggests that the 'leaky' ideal of freedom of the User continues into the domain of biosecurity where their extremely broad, vaguely defined agreement not to do harm with BioBricks is subject to the vagaries of community norms, and becomes a little like disciplining Users to make voluntary contributions.[93] It

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86 Alesandro Delfanti, *BioHackers: The Politics of Open Science* (Pluto Press, 2013).

87 Nelson, above n 54,153. Quotes technology policy researcher Davy van Doren who has documented a trend towards increasing patent applications in synthetic biology: 'We couldn't find any evidence that patent trends in synthetic biology might be different compared with other domains'.

88 Ibid 152.

89 Stephen Hilgartner, 'Novel Constitutions? New Regimes of Openness in Synthetic Biology' (2012) 7(2) *BioSocieties* 188.

90 Ibid 201.

91 Ibid 201–2.

92 Ibid.

93 Ibid 203.

would appear that the key stated normative values of iGEM, associated with sharing and communalism, may be the ones which are most difficult to articulate in practice, beyond the competition, or in future shaping of the field.

Aside from the tensions in different visions of Contributors and Users, it would appear that even some of the founders of the BioBrick concept are anxious about its legal viability in current IP regimes. For example, the registry holds many DNA sequences regularly used by teams that are already covered by patent claims:

> If iGEM was a for-profit competition then it would undoubtedly be sued for IP infringements. As it is currently an academic venture (with teams requiring an academic affiliation to participate), the incentive for patent holders to pursue litigation is limited, but this threat continuously hovers in the background, with the potential to be fatal to the whole operation.[94]

Another factor in this vexing IP context, which paradoxically may be contributing to iGEM's current 'success', is that many of the student-generated parts may be untrustworthy. This limits their value to commercial enterprises that otherwise might be more interested in taking them over, which would undermine the competition.[95] This suggests that for the concept of BioBricks to ultimately be successful it may need to move beyond iGEM into being organised in a more industrial or technocratic mode, where there are professional skills and financial resources directed to maintain appropriate quality control, and provide legal oversight, over their development.[96]

VI CONCLUSIONS: iGEM NORMS, COUNTER NORMS AND COMPETING VISIONS

Drawing upon the discussion above (in Section V), the ethos of iGEM appears to be based on matching Mitroff-like counter norms with Merton-like norms. In a succinct form these relationships could be expressed as follows:

- *(Following discussion in A):* To win a medal, a norm of double guessing judges and designing projects to match iGEM rules and benefit the BioBrick concept is encouraged. This co-exists with norms of academic curiosity for its own sake, and organised scepticism and research for community benefit.

- *(Following discussion in B):* To manage time constraints and be 'competitive', norms of privileging traditional disciplinary perspectives are encouraged. These norms co-exist with norms of universalism, interdisciplinarity, and collaboration.

- *(Following discussion in C):* To satisfy the competition's scientific and technical demands, norms of 'backstaging' concerns with Human Practices (social implications) are encouraged. These norms co-exist with norms of universalism, collaboration, and concerns with Human Practices (social implications).

- *(Following discussion in D):* To develop a career in synthetic biology and become wealthy, norms of individualism and ownership of intellectual property (interestedness) are encouraged. These co-exist alongside norms of communalism, community benefit, freeware, and teamwork.

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94 Jane Calvert, 'Ownership and Sharing in Synthetic Biology' (2012) 7(2) *Biosocieties* 169, 177.
95 Roberta Kwok, 'Five Hard Truths for Synthetic Biology' (2010) 463 *Nature* 288.
96 Rabinow and Bennett, above n 14, 66-69; Nelson, above n 54, 154.

Considering these norms and counter norms, it would appear that the culture of iGEM at present is unlikely to provide a normative ethos in synthetic biology that is coherent enough to promote (or inhibit) a new ethos for the field to address emerging issues of governance. Some values iGEM appear to be promoting in practice are consistent with its stated aspirations, while others are not.

Further, it is not clear that its stated aspirations are consistently shared by all those who are involved at a practical level, nor across the emerging field as a whole. Nor are they likely to be sustainable given current commercial realities and intricacies of intellectual property laws, and the mundane power relationships and institutional ecologies in the contemporary biosciences.[97] As was noted in the introduction to Section IV, iGEM fits most snuggly with a 'computer engineering' vision of the future of the field. More 'conservative' visions of synthetic biology as a continuation of synthetic chemistry, and more radical visions of DIY biology, intersect with iGEM but ultimately offer different imaginaries for the field's future development.[98]

Following Mulkay, and his observations about the rhetorical roles played by reference to norms as part of professional field building, it is not particularly surprising that identifying simple correspondence between common images of iGEM and its practices is far from a straightforward process. The image of iGEM as a model for a future synthetic biology scientific community has an obvious appeal for promoters of the field and university educators more generally. Youthful idealism and vigour, and the fact that students can develop considerable skills, communicate with other students, and enjoy themselves in the process, are hard things to be critical of — even if they do not clearly mesh with the development of a normative ethos that might encourage Mertonian or neo-Mertonian visions.

It may be the case that iGEM will continue to be re-shaped in response to challenges, 'flourish' and help facilitate the development of scientific-technical practice in some precincts of the field of synthetic biology. But policy makers need to make sure when they address the challenges of regulation and governance of synthetic biology, and iGEM's possible contributions to it, that they keep squarely in mind iGEM's limitations: that synthetic biology is an emerging field inspiring multiple visions for its future development; that iGEM inhabits one part of one particular vision of that future; and that aspirational visions of the development of an ideal iGEM ethical normative ethos often appear to be more consistent with promotional rhetoric than the contingencies of practice.

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[97] Rabinow, above n 78; Edmond and Mercer, above n 78; Caudill, above n 78.
[98] Bensuade Vincent, above n 45; Delfanti, above n 86.