Original Article

The BioBrick™ road

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Abstract Matters of intellectual property (IP) have been a characteristic concern of synthetic biology since its very birth as ‘open-source biology’. Although questions of IP in synthetic biology have intensified in recent years, little scholarly attention has yet been paid to the details of how such novel IP issues were actually first discussed and developed. In this article, I argue that a renewed orientation to specific empirical detail, to the bumpy road of untidy micropolitical stories and their piecemeal contributions – to the messy details of history – is essential in properly understanding the present IP landscape of this most contemporary of efforts to engineer life. Rather than coming out of any direct desire to gain legal clarity, concern for IP initially emerged organically out of larger discussions about the intended nature of the synthetic biology research community and its norms of openness and sharing. The goal of making biology ‘easier to engineer’ through the production of standard biological parts (BioBricks) has raised a number of these concerns in sharpest form. The emergence and development of IP issues in synthetic biology is thus best understood in the context of the ecology of practices and debates that have characterized the field in recent years.


Keywords: synthetic biology; intellectual property; BioBricks; iGEM; registry of standard biological parts; Drew Endy

‘Agreed. IANAL’ Drew Endy tweeted during the Synthetic Biology 5.0 conference, held on the Stanford University campus in June 2011. The acronym stood for ‘I am not a lawyer’ and came in response to incoming complaints that one of the keynote lectures of the day was not simultaneously webcast due to intellectual property (IP) concerns – a curious situation for a conference that had opened with a declaration of its commitment to engineering biology in an ‘open and ethical manner’. Either such words were conveniently protean for a Foundation whose motto had recently become ‘Biotechnology in the public interest’, or the oversight was a dramatic contradiction. Endy immediately acknowledged as much: ‘Ting’s talk not webcast due to IP issues. 100 per cent appropriate to hassle me; just found out. We’ll be back ASAP’. Rob Carlson of Biodesic took him up on the offer, tweeting ‘Hassle Hassle Hassle’, and questioning, ‘Doesn’t this count as public disclosure’? ‘Agreed’, Endy tweeted in return, ‘IANAL’.1

1 All written sources are quoted verbatim from the published source; all spoken sources are transcribed as heard.
Nevertheless, the matter was not resolved and approximately 95 online viewers were unable to watch the talk.

Matters of IP have been a characteristic and recurring concern of synthetic biology since its very birth, and seem to be increasing. Many lawyers, legal theorists, science and technology scholars, and others – including synthetic biologists themselves – have sought to pronounce on the new IP landscapes that synthetic biology might be engendering, pointing to variously emerging modes of IP enforcement ranging from material transfer agreements to contracts. Others have been quick to point instead to historical antecedents and, indeed, many recent IP developments in synthetic biology – from the creation of shared registries and parts held in common to the rumored status of the ‘research exemption’ to patent law for academic research, a new form of ‘breeder’s privilege’ – return in new ways to themes already a century old. Characterizing what is most novel and placing contemporary research into a broader historical context are both important dimensions to bear in mind when characterizing the present state of synthetic biology. To date, however, the literature on the place of IP in synthetic biology has remained somewhat impoverished, dealing largely with abstractions and lacking a more granular description of how IP issues were actually hashed out in a preliminary form during a series of ongoing meetings and workshops in the synthetic biology community. Closer attention to such details, and to the decisions of various institutional players, reveals that in fact there is no immediately obvious pattern, uniformity or singular orientation toward IP issues in synthetic biology – just as there is in fact no one thing called ‘synthetic biology’. Craig Venter’s coining of the term ‘synthetic genomics’ for his specific areas of interest (and, not coincidentally, the name of his company – Synthetic Genomics Inc.), might seem to attest in its very coinage to a potentially new constellation of IP interests in synthetic biology, but matters of IP have in fact been a contested part of synthetic biology since its very birth – ‘open-source biology’ was even one of the first names proposed for the field in the late 1990s.² Perhaps the best illustration of these ongoing contestations comes from the presentation delivered immediately before the blacked-out talk, when Harvard University’s George Church began his talk by showing a slide covered with nearly 50 corporate logos and governmental agency insignias. Church introduced this as his ‘conflict of interest’ slide, to a great round of knowing laughter from the audience.

Despite the deterministic implications of the metaphorical ‘emerging technology’ label, synthetic biology today remains a diverse collection of endeavors, technologies and actors. To reify and ossify such a complex social constellation would be to miss the phenomenon of interest entirely. When seeking to assess the place and future of IP in synthetic biology, therefore, a turn to careful fieldwork seems worthwhile instead. The particular details of how certain decisions were made – the contingency of specific moments – and how certain issues were seen to be relevant by key engaged actors can be an important antidote to vague generalizations, and can better illustrate how the modes of engagement of synthetic biology with matters of IP are as diverse as the field’s many different practitioners. In short, a renewed orientation to specific empirical detail, to the bumpy road of untidy micropolitical stories and their piecemeal contributions – to the messy details of history – seems essential in properly characterizing the present IP landscape of this most contemporary of efforts to engineer life.

² For more on the early history of synthetic biology, see Campos (2009).
Toward that end, this article concentrates on the emergence of IP issues in the development of ‘standard biological parts’ known as BioBricks™. Although BioBricks™ are frequently referenced in the literature, many of the on-the-ground details of the IP dimensions of the BioBrick™ story have as yet escaped scholarly attention. Rather than rehearse a mere chronology of events leading toward the recently released BioBrick™ Public Agreement (BPA) – an important IP milestone and the orchestrated climax of the 5.0 conference – I seek here instead to offer background and nuance to a story that is all too readily told as one of increasing ‘democratization’, ‘promise and peril’, ‘freedom’ or any of several other ready-to-hand frameworks of resolution. Rather than coming out of any direct desire to gain legal clarity, IP concerns in synthetic biology in fact largely initially emerged out of a complex ecology of practices surrounding BioBricks™. Greater empirical richness, based on actual fieldwork at several early workshops and conferences, and a more detailed attention to the technological infrastructures, novel moral economies and varied normative dimensions of social engineering, may thus help to better illuminate the complex history and present dynamics of IP issues in synthetic biology today, and may offer ripe fruit for future analyses.

Envisioning: iGEM and the Registry of Standard Biological Parts

One of the earliest names proposed in the late 1990s for what would later be known as synthetic biology was ‘open-source biology’ – a label that clearly drew inspiration and metaphors from the open-source software and internet industries. Such inspirations also reveal a structuring assumption synthetic biology shared with the logic of the patenting system and with engineering more broadly. For early synthetic biologists, to understand something properly meant to understand how it was made and how it worked – to ‘see the source code’ – and then to be able to reproduce it successfully oneself, intentionally, in a biological system. As groups of synthetic biologists at workshops and conferences and in laboratories and over coffee envisioned and then sought clarity regarding the nature of an inchoate ‘standard biological part’ and technical standards, and as they began to create a common pool of standardized biological parts listed in a common registry, they began to struggle with new possibilities and new intersections of their work with what they would only later begin to consciously characterize as matters of IP. General concerns about the putatively ‘revolutionary’ branding of synthetic biology, and about the ownership of ideas, and the relationship of the new field to extant techniques and traditions of scientific knowledge had emerged early on as a sore point in the international and cross-cultural dimensions of the early history of synthetic biology. But revolutionary rhetoric aside, the rapid emergence of an ever-larger collection of open-source ‘biobricks’ raised urgent practical questions that – though they were not always understood in such terms – soon bled into the realm of IP. Rather than coming out of any direct desire to gain legal clarity, IP issues in synthetic biology thus emerged in a more organic fashion out of larger discussions about the intended ‘open’ nature of the synthetic biology research community. Who was in charge of the newly emerging commons? How to make sure that its contents would remain protected and available for use by all? How to encourage further innovation? How much should be revealed of works in progress and how much was too much? Openness was a central value – Endy so reflexively valued practices of openness
that he often shared his laboratory notes on open wikis and warned his correspondents that any e-mails sent to him were subject to broader dissemination – but too much openness could be a liability. Divining the ‘intentions’ – current and future – of practitioners and patent trolls alike proved a brisk business as synthetic biologists began to propose technological, ethical and legal solutions to such concerns emerging from an increasingly complicated ecology of practice. By the time of the 5.0 conference in June 2011, with the formal unveiling and inauguration of the BPA, such IP concerns had become central, conscious and recurring themes. As the compelling and visionary idea of a ‘biobrick’ had become the legal reality of a BioBrick™, a field initially full of claims of ‘IANAL’ had been both wittingly and unwittingly educating itself in the ways of the law.

In 2003, however, IP concerns were far less prominent. Slogans such as ‘Making life better, one part at a time’ were instead the mottos of the synthetic biology working group at MIT, where Tom Knight of the Computer Science and Artificial Intelligence Laboratory had pitched the idea of a ‘BioBrick standard biological part’ to his colleagues, including Drew Endy, for some years.³ Knight had already done much by this time to formalize the procedure for making a BioBrick, and laid out the specifications in a form modeled after Texas Instruments’ textbook of transistor–transistor logic for the construction of integrated circuits, The TTL Data Book for Design Engineers.⁴ By 2004, Knight had lectured on ‘Biological Simplicity’, using Legos™ to illustrate his ideas of standardized parts: ‘You can put them together however you want’ (Clark, 2004). The cover of Knight’s seminal report even featured Legos™ strewn over a copy of the TTL Data Book. Although engineers often found the concept of a standard biological part exciting, Knight noted that biologists were generally nonplussed: ‘They are not excited. Nor should they be. It’s a different agenda’ (Aldhous, 2006).

Knight and Endy, however, found valuable colleagues in each other. While at the Molecular Sciences Institute in California in 1999, Endy had already written an internal report for DARPA (the Defense Advanced Research Projects Agency) entitled ‘A Standard Parts List for Biological Circuitry’. After having met Knight and valuing his insights, Endy increasingly came to appreciate the impact shared standards had had and could have on technical communities.

Endy introduced Knight’s concept of the ‘biobrick’ at the inaugural Synthetic Biology 1.0 conference in 2004, and suggested to the nascent community a new vision of a composable biology – ‘parts’ could be linked together to create ‘devices’ that could in turn be linked together to create larger ‘systems’ to accomplish desired biotechnological and human-desired functions. By tying in this ‘abstraction hierarchy’ that would make biology ‘easier to engineer’ with the new concept of a ‘biobrick part’, and drawing on the ingenuity and energy of undergraduate students at MIT, the International Genetically Engineered Machine (iGEM) competition – designed primarily for undergraduate students – was primed for take-off.

iGEM had begun at MIT in 2003, when four MIT faculty members (Endy, Knight, Randy Rettberg and Gerald Sussman) came together to offer a small course during MIT’s January ‘Independent Activity Period’, where students were challenged to make ‘blinking cells’ (Rettberg and Endy had initially proposed calling the event ‘bug wars’, but later sought

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³ For more on Drew Endy’s role in synthetic biology and his first encounter with Knight, see Campos (2012).
a different name). The ultimate goal was to treat biology as a kind of technology. IP concerns seemed far from prominent at the time.

The course was a success. In succeeding years, iGEM was said to have grown ‘out of this desire to test the hypothesis’ that biology could be made easier to engineer by the use of a common pool of standardized interchangeable parts, kept in a centralized repository with an associated registry. Eventually, this in-house collection for iGEM became known as the Registry of Standard Biological Parts, ‘a continuously growing collection of genetic parts that can be mixed and matched to build synthetic biology devices and systems’ and which was said to be ‘a work in progress’.5

The physical repository for iGEM’s Registry of Standard Biological Parts existed deep within the bowels of MIT, behind an unremarkable door festooned with iGEM’s insignia and kept solid in a −80°C freezer. By 2010, over 7000 (and growing) clones of submitted ‘parts’ were maintained as bacterial stocks in aliquot tubes and on plates. The Registry was constituted as a common pool for research, and most of the contributions to the Registry emerged from the varied iGEM teams. Over the years, as iGEM attendance continued to double – from four teams in 2004 to 165 teams totaling over a thousand participants by 2011 – the number of parts in the Registry grew accordingly. Synthetic biology had gained a youthful and powerful new engine for ongoing part development – even as discussions about what exactly constituted a part continued apace. Living technologies, model organisms, hardware primitives, moral economies, central repositories, exchange networks – these are common features in the history of biology over the last century. And like the construction of earlier seedhouses for the propagating, packaging and distribution of thousands of seeds, within a few years the Registry was regularly shipping multiple tens of thousands of parts to iGEM students per year.

The Registry was Rettberg’s baby. He was especially well suited for the job of handling a centralized repository of open-source tools for a new technological field, having begun his career working on the ARPAnet (Advanced Research Projects Agency Network), a forerunner to the internet involving only two dozen computers. He later designed the first transmission control protocol and internet protocol (TCP/IP) for UNIX, early components of internet packet-switching. After years of working at the internet company BBN, Apple and then at Sun Microsystems, where he was chief technical officer of the storage division, Rettberg took on a position in Knight’s lab as an unpaid research affiliate while he learned the basics of biology. Soon enough, though, he had taken on a new role: creating the Registry of Standard Biological Parts. Running the Registry was both great work and great fun for Rettberg. The Registry, as a central component of iGEM, placed Rettberg in a position of great power in the nascent field. With each passing year, Rettberg refined the rules of iGEM to deal with new threats to its amateur and open nature by instituting open team wikis and wiki-freeze dates before the competition, increasingly articulated requirements for submission, and firm deadlines, among other important innovations, each of which was ultimately intended to serve to strengthen the community and the Registry.

iGEM had set out to create a veritable utopian commons, and it might have been but for various problems with the original biobrick standard Knight had proposed. Biobrick parts, 5 http://partsregistry.org/Main_Page.
devised with ‘prefix’ and ‘suffix’ points of attachment that enabled their use in a ‘plug-and-play biology’, inevitably left a small scar of disruptive DNA when stitched together. The original Knight biobrick standard (later referred to as ‘Biobricks alpha’, BBz, or simply BBa) inevitably led to the creation of an eight-base ‘scar’ that would correspondingly throw genetic transcription out-of-frame (codons and their corresponding amino acids are based on triplets). Such scars unnecessarily complicated downstream protein synthesis, which required the linking of adjacent amino acids. This was an inauspicious – though in retrospect a not entirely unexpected – complication for a new biology designed by an engineer rather than a biologist. What’s more, this ‘original’ version was actually the third iteration of Knight’s standard (‘nobody else saw the first two, thank goodness’, he said in 2006).

This design flaw meant that even Knight’s close colleague, Rettberg, could state by 2008 that ‘we have the TK assembly standard 1.0, which I don’t believe in’. For his part, Endy also joked about the ‘Tom Knight Assembly Standard #1 … reusing language that has already been used with a technical mismatch and screwing a whole bunch of things up’, concluding that 90 per cent of people ‘think it is really stupid’. With the original gold standard thrown into question, a variety of other ‘assembly standards’ were proposed in quick order. The ‘silver’ standard, based on Ira Phillips’ work in Pam Silver’s lab at Harvard Medical School, was an honorable attempt at a new standard. Each reworking of the standard assembly methods produced different scars and presented novel issues, however (Phillips and Silver, 2006). The ideal form a ‘part’ should take was not yet clear.

Although restriction-compatible to the first standard, the Silver standard remained only that, and was succeeded by a variety of other standards and assembly methods from Freiburg, UC Berkeley, and a revised format from Knight, among others (BioBricks Foundation (BBF), 2009). And yet, by November 2008, most iGEM teams (the event now included 600–800 students) continued to use the original BBa standard despite its flaws. In an attempt to reconcile the competing standards – or rather, the different methods competing to become a standard – efforts were made to specify standards in a way that emerged from popular and common practice. ‘The work of the BBF is to support this open technical standards setting process’, Endy said at a BBF workshop in 2009. Explicitly following the model of the development of the ARPAnet, he initiated an ‘RFC’ (request-for-comment) system, with sequentially numbered proposals outlining the specifics of each proposed technical standard. It was a form of crowdsourcing: whichever RFCs were most useful and adopted by the community would ultimately guide the majority of further development. (Interestingly, these RFCs were themselves in turn copyrighted.)

Solving such difficulties in setting technical standards did not help solve the larger metaphysical question of the nature of a ‘part’, however, a question whose answer held direct implications for the development of a clear system of IP in synthetic biology. ‘I think that nobody really knows what a part is’, said one workshop participant, early on. ‘There is no agreement in the community, and there are probably good reasons for this’. The abstraction hierarchy, so beloved by engineers and a central feature of Endy’s initial publicly articulated vision for synthetic biology, proved a less than obvious tool for thinking about the standardization of biology. Ascertaining the proper level of granularity proved difficult: Was a ‘part’ a nucleotide base? a stretch of DNA sequence? a promoter? a gene? ‘The right level of granularity is where you can put a scar without affecting functioning’, one participant proposed. ‘But the answer is not completely obvious, and there is probably no
consensus in the community about this’. It was evidently worth thinking about what a biological part was, and not only for technical reasons.

With the emergence in recent years of four or five different major ‘schools’ of synthetic biology – parts-based, metabolic engineering, minimal genomes, minimal organisms and origins of life research – Endy had long since given up publicly attempting to impose a single unified definition of synthetic biology. But he was increasingly bothered by the fact that a number of researchers were presenting parts that they putatively described as ‘biobricks’ and yet which were not compatible with the parts already contained in the Registry of Standard Biological Parts. Already by late summer 2007, Endy saw the need to constrain and refine the meaning of ‘biobrick’, and trademarked both ‘BioBrick’ and ‘BioBricks’ under the auspices of the newly created BBF. ‘For the next 10 years in the US’, Endy reported, ‘these are registered marks held by BBF’.

Ironically, then, the ‘BioBrick’ became trademarked in response to the same sorts of freewheeling creative activities that Endy and others had initially believed best characterized the free and open nature of the new ‘open-source biology’, which the Registry was supposed to make possible. In order to protect the vision of a future of standardized biological parts making biology easier to engineer, Endy felt it was necessary not only to create a registry and repository for sharing parts, and to ensure compliance with a standard, but also to go further and create a nascent IP structure that would guarantee the functionality of interchangeable parts – ‘truth in advertising’ – while reinforcing the openness and sharing ethos of the community’s registry and repository. The BBF was thus established both to actively police the kinds of parts that could properly be termed ‘BioBricks’, and to serve as a form of legal protection insulating the work of the nascent synthetic biology community from patent trolls who might use the Registry for their own fencing-in ends. (‘The BBF maintains the “biobrick(s)” trademarks in order to enable and defend the set of BioBrick™ standard biological parts as an open and free-to-use collection of standard biological parts’, noted the BBF online FAQ.) It was also around this time that Endy began to insist that the word ‘BioBrick™’ be used primarily as an adjective rather than a noun, a grammatical shift that was a short-lived part of a larger disciplining.6

The BBF ‘started to pull off this hack’, Endy said. ‘Let’s get BioBricks™!’ Rather than allowing exclusive ownership, Endy intended to continue the dream of an open-source biology and encouraged the new members of the BBF to imagine a ‘network economy, where competition takes place around networks and services, not limited access to widgets’. By 2009, the BBF had over 500 ‘members’. The benefits of membership were not entirely clear, but more than 80 people joined a ‘technical standards’ group, and more than 60 signed up to join a ‘legal working group’.

From their very inception under the auspices of the Foundation, BioBrick™ parts were thus simultaneously technical and legal objects. Just what they were ontologically was less clear. For Endy, a part was effectively ‘any basic biological function that can be encoded as DNA’. DNA came first, and was real, while all other higher taxonomic levels of the abstraction hierarchy were merely conventional: ‘everything else is … we just make it up, right? Parts are human-defined objects, they are bits of genetic material, DNA, that carry out functions

inside cells ... it’s a basic function that would make up a programming language [a primitive] .... It would be like a print statement’. While forced to restrain his terminology in a trademarked legal context, he let metaphors fly loose where he could and called for a reinvention of a programming language ‘that would permit the programming of DNA. Once you get to parts, then you immediately start to put parts together to make more powerful objects. We get to make these up, we call them devices ... [and then] still more powerful objects, again we’re just making this up, we call it “systems”’. It may have been made up, and the ontological status of parts may not yet have been entirely clear to participants or onlookers, but Endy attempted to transform BioBrick™ parts into quasi-legal entities, protected from usurpation both by trademark and common usage – although by little else at this point. Both the ontology and the IP status of devices and other higher combinations of parts, however, remained entirely undetermined.

The Registry’s problems were hardly all conceptual and legal, however. One synthetic biologist and team-leader at Virginia Tech had analyzed and found the Registry to be beset with serious problems ranging from empty descriptions and sequence-to-sample mismatch errors to plain old miscategorizations (some elements listed as terminators were in fact promoters) (see Peccoud et al, 2008). Although plant patent law in the 1930s had constructed a way to sidestep the depository requirement by construing plants as single units (rather than as collections of parts) and requiring the inclusion of an overall description and image, the situation seemed oddly transformed in the case of the Registry (Pottage and Sherman, 2007). One could deposit the part – indeed was mandated to do so as a condition of access to iGEM – but need not, de facto, supply any accompanying description of the part submitted. This was a recipe for downstream complications.

Although earlier generations of plant breeders and other associated biological engineers had struggled with how to provide IP protection for sexually reproducing species whose continuity of traits could not be assured with the technology of the time, in the case of the Registry not only was the ontological status of the parts it contained unclear, but their empirical status was often unclear as well: just what was in the aliquot containers in deep freeze? Often, only the undergraduates who submitted it knew. Endy also noted at one time that ‘of the 500-plus promoters listed in current registries ... fewer than 50 have been measured’. Correlating the informational sequence available in the Registry with the actual wet DNA in the repository freezer remained an ongoing challenge for several years. Concerns with quality control, standardization in the deposition and characterization of parts, and even the logistics of distribution were some of the other issues surrounding the synthetic uses of sequence information, and were much more pressing to practitioners than most legal concerns. Although a ‘part’ was conceptually a powerful idea, and increasingly a brand with great selling power, it was proving remarkably difficult in the nascent synthetic biology to precisely fix a biological part not only ontologically, but also many times even empirically.

Internal questions also arose about what the standards ought to be for characterizing a part, and for providing documentation that would enable other researchers to know what the part was good for. If one were lucky, such information was provided for in the documentation for the part in question. Having a Registry with parts that were absent, misidentified or improperly characterized, however, provided a number of challenges to any immediate translation of legal principles about a commons, disclosure or protection of
community work. If a part might not even be contained in the repository, was the Registry really then a mechanism for enabling disclosure? The complicated on-the-ground reality of the Registry makes it seem an unlikely starting point for a new ‘open-source’ biology increasingly concerned with matters of IP, though in fact it came to play just this role.

Several repeated interactions of the Registry’s creator, Rettberg, with the upper echelons of MIT administration and legal counsel initially served to bring IP concerns – among other legal issues – more prominently to the fore. When questioned at the iGEM jamboree in 2009 about the place, purpose and functioning of the Registry, Rettberg complained about the unpleasant intrusions of lawyers into a realm previously governed by shared norms alone. But it was already clear that the internal development of moral norms and the relatively simple iGEM regulations, which had once implicitly governed all users of the Registry, were not sufficient for the needs of the nascent community. Talk of a professional code of conduct was bandied about, among other suggestions, and as fears of patent trolling began to emerge (‘Microbesoft’, in the ETC Group’s memorable coinage), questions of registries, repositories, technical standards and community behavior came increasingly to be seen not only as practical concerns, but also as concerns couched in the language of IP. The Registry itself, first envisioned as part of a general goal of initiating a standardized approach to ‘make biology easier to engineer’ and subsequently developed as a mechanism for competing iGEM students to share parts and develop the new field, was increasingly discussed in the synthetic biology community as if it were a means to prevent unwanted intrusions from patent trolls – all the while, as actually constituted, remaining entirely vulnerable to such a threat.

The Registry itself was never entirely satisfactory to begin with, never a one-size-fits-all solution. The new putatively ‘open-source biology’, if it wanted to be effective at larger scales, found that it could hardly remain entirely ‘open’ for long. The issue was how the Registry might best help drive the creation of an effective new industry based on standard biological parts held in common. Although openness and publicly accessible wikis were the norm for iGEM teams using the Registry, such unalloyed openness was not as attractive to researchers working in other moral economies where priority and credit mattered intensely, such as academic and corporate laboratories. Publishing aspects of the workflow process – transient data and other constructs – in an online public forum or wiki might work for students engaged in a supposedly ‘open-source biology’, but for some other professional users of the Registry not involved with iGEM – never a large number compared with student users – private ‘sandboxes’ where work could be developed in private and where one could choose which information or constructs to make publicly available were a preferred option. ‘If we want synthetic biology to go industrial’, some participants had noted early on, ‘industries are not going to use open source’ – and, indeed, few corporations to date have shown interest in using the Registry. Rettberg actively sought to address these concerns of individual labs and other non-iGEM users by indicating he would provide support for ‘private spaces’ that would not present parts publicly until desired.

If the Registry proved too open for the comfort of many academic and corporate laboratories, however, it also seemed in other respects too closed for the likings of some of its potentially most valuable contributors. As creator and manager of the Registry, Rettberg had apparently refrained from revealing its software coding. The Registry was accordingly grumbled about by some as a form of ‘closed-source’ code development and top-down control, seemingly at odds with the emerging open-source nature of the field – yet one more
obstacle to researchers, especially those outside of iGEM, who might be seeking to integrate knowledge and tools across laboratories and computer platforms.

In programming terms, the Registry was described by Rettberg as one interface with two sides: a database side (consisting of tools, the user interface, and PERL objects, giving a normal CGI presentation and running off of a MySQL database), and a MediaWiki engine with the same look and feel. As the field developed, the MediaWiki interface proved to be a crucial intermediary, allowing access to the commons for information coming from other registries and sources that would otherwise not be readily incorporated. But to some, including those at the Department of Energy’s Joint BioEnergy Institute (JBEI) in Emeryville, it simply seemed paradoxical that Rettberg refused to make the Registry open source. JBEI became committed to developing its own open-source databases and registry, for a host of technical, convenience and ethical reasons – ‘instead of having a monolithic central database where everything is public as soon as you hit the save button’, as one registry designer noted. Other newly developed portable web-based registries, such as BrickIt, similarly sought to permit the cataloging of local biobrick (though not necessarily BioBrick™) samples.

Several new registries emerged as various researchers and institutions felt a need to develop alternatives that would enable users to store parts from their own labs, constructs that were not yet ready for the limelight. Alternative registries thus performed acts of enclosure, becoming in some cases forms of private recordkeeping for labs and individuals, or with differing degrees of privacy and publicity. A registry need not be envisioned solely as a commons. Moreover, with eminently understandable and traditionally private methods of recordkeeping competing with the nascent field’s stated goals of openness, boundaries between ‘private’ and ‘shared’ were being actively renegotiated through the existence of such registries – and all this despite the original Registry’s stated goal of creating an effective commons for the development of the new field and hoped-for industry of synthetic biology.

The ironies were mounting: a vision of standard biological parts and a corresponding Registry had been trumpeted as a novel commons, and yet the Registry itself was not open source in its coding; and its status as a ‘commons’ was challenged by several newcomer frameworks throwing the entire concept of a commons into doubt. Moreover, the differing levels of public disclosure in different registries only increased potential confusion about the legal IP status of entities they contained. Did different objects in the Registry have different IP statuses, depending on the degree of public access they permitted, or depending on the nature of the registry in which they were contained? What was being disclosed and how? And finally, the Registry itself was full of trademarked entities – and some were even patented. Far from being some abstract intellectual matter or derived directly from prophetic visions of an ‘open-source biology’, questions of IP in synthetic biology emerged directly out of questions about the proper place and functioning of the Registry in the nascent field’s emerging ecology of practices.

The shift from a known, centralized and monolithic registry to newcomer, decentralized and devolved registries was already well underway by 2008. Even those who found the parts paradigm ‘wonderfully useful’ or were in charge of the primary registries themselves found merit in proposals for a ‘web of registries’ flexible enough to accept different standards, to accommodate existing strain and plasmid data and to communicate with other registries by common, rather than bespoke, interfaces (such as XML). Open-source and proprietary systems were increasingly being created side by side – even though the
‘proprietary’ system of the iGEM Registry had been cited as being too ‘open’ for corporate interest! Not only then was there no agreement on what constituted a part, no agreement on how parts could best be maintained and no shared standard, there were now multiple registries. Following such new developments, even Rettberg agreed that there would ultimately be no one comprehensive ‘Sears catalog, one catalog of all online products. Rather individual labs and groups will want to represent themselves and will want to do that representation themselves, and so it will be necessary to have quite a few different registries’. Some proposed registries were only digital databases, whereas others called for such databases to be combined with repositories of physical samples. The exact nature of emerging ‘registries’ and ‘repositories’ remained in flux. A new metaphor beyond ‘the commons’ and more consonant with the ways of the internet age was clearly needed to describe the emerging realities of such a hyperlinked web of registries and repositories. The dream of a universal commons – while a seemingly necessary legal fiction for further legal work on the concept of the BioBrick – was in reality surpassed by the complexities of an emerging ecology of practice. This is perhaps best seen in Rettberg’s simplest argument for redundant registries and repositories: in any single given country or institution, ‘the lawyers could come in, [and] shut things down’.

Ultimately, Rettberg modestly claimed to offer no ‘big single solution’ and proposed a variety of possible futures. Drawing inspiration from the architecture of the Internet, he said in 2007: ‘I imagine something more like this, lots of different files and a database box at the bottom, [with] viewers, tools, users that form the web themselves, as one of different things that can be composed’. Rettberg even proposed that should the new registries prove better, the original Registry could then ‘offer a solid, centralized, highly reliable back-end storage for that whole collection of registries’. And should those registries take off after a year, ‘it would be great to have the current Registry go out of business. The only problem is that we don’t actually know the timeframe’ for such successes, should they occur.

Community-based web-tools for registries were thus increasingly seen to be as important as physical repositories. Even as Rettberg sought to make sequences available in XML (and efforts were made to include other non-sequence information, such as images), he was forced to make tough decisions about the nature of the Registry against an ever-impending iGEM timeline. He could not wait to see which of the several different open-source registries might come to be best accepted as the community standard. ‘We have a couple of different open-source registries going on’, synthetic biologist Reshma Shetty noted at one workshop in 2008. ‘Now is that the best approach, because we’re still trying to work out the kinks ... or ... should [we] pay the overhead and be trying to coordinate efforts?’ Indeed, the question of how solid alternate systems would be, both in terms of personnel support (what if their developers went on to other projects?) and in terms of capacity design (could a new system handle the annual iGEM influx?), were central concerns for Rettberg by this time and not to be dismissed or passed over lightly. As the architect and administrator of the Registry, Rettberg feared that if the wrong decision were made, it would be a ‘horrible, horrible’ mess. Decisions about the Registry – and about the actual instantiation of a commons seen to be central to protecting the promise of an open-source biology – were based less on ultimate legal concerns than on proximate technical and ethical ones.
Refactoring: From Community to Industry

This is not to say that the legal concerns were minor. In fact, the perceived necessity for a legal scheme to resolve IP concerns and to permit the existence of a kind of open-source biology emerged precisely in the matrix of attempts to couple technical standards, interfaces and repositories with the interests of varied actors. Synthetic biologists invited lawyers, consultants and other interested parties to hash out the details with them in open brainstorming sessions in undergraduate lecture halls and closed-door meetings in wood-paneled suites. Already by March 2006, the Project on Information Technology and Homeland Security at UC Berkeley’s Goldman School of Public Policy had hosted a workshop of ‘synthetic biologists and innovation economists’, who concluded that ‘IP policy is a potentially powerful lever for “tipping” synthetic biology to a LINUX-like solution in which basic modules are freely available to everyone. At the same time, companies may donate more (and more ambitious) parts if they are allowed to retain at least some IP rights for a limited period of time’. With constant references to historical examples from the world of software, this workshop struggled to come to terms with these complex issues.

Further meetings were held in 2008 and 2009, this time under the auspices of the BBF, to address matters of IP in synthetic biology among other issues. At these later workshops, several other possible mechanisms were suggested, such as a ‘viral component’ like that of the GNU General Public License (GPL) that would ensure that ‘if you release a product … it triggers distribution of source code’. Others proposed a ‘give and get’ framework. The primary motivator for such IP concerns was the protection of the open-source registry against would-be trolls. Rettberg still held out hope that lawyers somehow wouldn’t be necessary: if the Registry as BioBricks commons could be protected ‘probably in a magic way … so nobody could claim it … then we wouldn’t need any of this framework’ – a comment that made a visiting lawyer actually laugh out loud.

But IP concerns ran the other direction as well. ‘Is there a *de facto* research or education exemption?’ Rettberg asked. ‘There is not an actual research exemption. The courts struck that down. There is a *de facto* one, and will it work for iGEM in the future? I worry that some patent troll will send a letter to MIT and I will be shut down’. Belief in a ‘research exemption’ was one of several ethereal IP elements associated with BioBricks before the emergence of the final BPA at the Synthetic Biology 5.0 meeting in June 2011, and upon which – along with ignorance and much goodwill – the entire edifice rested in no small measure. Endy had long argued for the existence of a research exemption, and repeated the claim at several earlier meetings and workshops. When he was told at one workshop that such an exemption did not, in fact, exist, he contested by saying that it *did* exist and then he corrected himself, saying that it ‘does not exist, but that it does exist’ – a syntactically contradictory statement that nevertheless semantically contained a world of meaning.7

7 Endy referred on another occasion to ‘Hippie academics at iGEM pretending there’s a research exemption and pretending successfully’. In fact, the research exemption has proven to be a mainstay of Endy’s reasoning. When asked by Hamilton Smith at the 4.0 conference in Hong Kong in 2008 if there was a lot of red tape in the Registry’s distribution system, Endy responded: ‘at the moment, not being the distributor of these components directly, what I can say is that I know of no paperwork involved whatsoever. In a large part that depends on one’s belief in a research exemption’.
good idea because it let us get started with the work’, Endy noted in 2008, ‘but we don’t really know what that means yet’. One major challenge that immediately emerged, he continued, was the actual distinction between a part and a system:

what’s really the difference between the two? What’s to say that tumor-destroying bacteria is a system today, but five years from now it might … become my base unit? As we get better and better at engineering biology the things that are at the top of this abstraction hierarchy might in a relative sense move lower and lower and lower. So we don’t yet have a formal scheme from a legal perspective about how to keep some things open and other things protectable by conventional IP such that you can commercialize them within the existing marketplace.

And so what had previously been primarily a methodological, ontological and empirical question now essentially became a legal question as well: Just what was a part? While in 2006 Endy had noted that DNA clearly fit at the part level, and that all higher levels above DNA were conventional – ‘everything else is … we just make it up, right’? – by 2008 he was keenly aware of the additional IP issues that this might present. If the definition of ‘part’ were time- and context-dependent, and a novel form of ‘breeder’s privilege’ extended to parts but not to patentable devices produced from parts, what coherence was there in such a system? He envisioned that these problems would only magnify as increasingly more powerful DNA synthesis technology came online, and as 50–1000 components were included in an integrated system. ‘We have to figure out how to interface with this issue’, Endy noted. The BBF could act to spoil patents, serve as a clearinghouse, or to license use; or it could advocate developing a new *sui generis* type of IP framework for standardized biological parts: ‘If we’re rebuilding the living world we might have to expect rebuilding part of the legal scheme’, he proposed.

Endy had long dreamed of building ‘a diverse industry of next-generation biotechnology, an open collection, and a standards layer of standardized biological parts’. This was important, he felt, because the costs of working around an IP restriction – if ‘some jackass has ownership on a particular object’ – could range from free or trivial, if one could collect another sample from nature, to infinite if one were seeking a unique, owned sample. Therefore, among ‘the limited set of things we want to be doing’, Endy noted, was establishing an ‘open collection of biobrick parts’ and ‘building an industry on top of this that is consistent with our values’, which would grow in the extant innovation landscape. ‘Really what we’re doing is we’re building out an alternative, something that’s different in the ecology of ownership, sharing, and innovation’, he noted, ‘so that people could choose to do something different’. Without such an option, he concluded, ‘they’re never going to do that’. Canadian venture capitalist Andrew Hessel agreed: ‘BioBrick parts will lead to applications that should be commercialized to the world. The real thing I don’t want to see is proprietary ownership of the entire foundation. I want an industry. I want a big industry. I just don’t want it to be a proprietary industry’. Rettberg also agreed: the current ideology held that ‘innovation requires ownership of ideas. And that’s not necessarily true’, he noted. ‘It’s not necessarily the case for many industries’.

Endy also raised the question of how the Bayh-Dole Act might have affected such dreams for an open-source biology, when federally funded university research in the United States
was required to orient itself to eventual application and commercialization. The commons that Endy hoped to establish was thus also, in part, an attempt to find a way to use IP structures to fight dominant and federally mandated trends in the applications of IP to contemporary science and engineering in the American context, and to envision alternative ways of building industrial applications.

But were there any lessons from history here? One workshop group member asked whether there were any lessons to be had from the electronics industry. Endy responded by saying that Texas Instruments (source of the *TTL Data Book* that inspired Knight) had been ‘able to afford to make these foundational infrastructural investments because they were making so much money developing weapons systems. If we could start a biological war, there’d be plenty of money to develop standard biological parts. But I don’t want to do that’. He said he had even attempted to contact the institutional historians at Texas Instruments to gain further insights, and had learned in the process that the relevant histories were in fact distinct for Intel and for IBM. In other words, there were no unequivocal HistoryBricks with which to build: ‘I think we have to make our own world is what it comes down to’, he concluded. Synthetic biologists would have to invent ‘a totally different way of viewing ownership and sharing of Biobrick parts’.

What had thus seemed antithetical or contradictory to some earlier on – Endy’s quest for an open-source biology that permitted both personal and corporate investment – was now being synthesized as Endy drew on historical examples to reason and to illustrate how an open-source approach based on standardization could actually help drive commercial development, and argued how such openness could and should be protected with an IP structure yet to be devised. ‘The question really is going to become, you know, do we put a bridge between research exemption and legal limbo’, he said, ‘which is what we’re operating in, and copyright and *sui generis* which is where we end up … How we put a bridge … that is what is most interesting to me’. Endy repeatedly recommended looking at historical cases to see how standards were set in practice, when they worked and when they didn’t, to better understand the role for government, and to better understand how to institutionalize a standard. Evidently, HistoryBricks were good to think with, even though they couldn’t be built with.

Could one NGO hope to institutionalize a technical standard or an IP framework for an entire field? Again, Endy thought, history might provide a clue. If BioBricks were to become protected by trademark, this could become a way to organize an industry – though this was ‘not anything more than a notion at this point’, Endy noted. The long but still fruitless path from standardization to technology platforms and industrial foundations – Endy’s dream that first emerged as BioBricks and would later reemerge as his vision for a ‘bio fab’ – was for Endy either ‘exciting or sad depending on how long you’ve been following that story’.

**Decoupling: The BBF**

The bridge-building began with the establishment of the BBF. Established as a 501(c)(3) nonprofit organization under Massachusetts law in the middle of 2005 – shortly after the founding of the synthetic biology companies Codon Devices, SynGenomics and Amyris Technologies – the BBF was deliberately intended as a response to the increasing
commercialization of synthetic biology. Endy felt in 2005 that it was ‘the right time to lay the organizational framework to make sure open-source BioBricks can exist as an alternative’, even though he personally had a stake in the financial well-being of Codon Devices (a company he had described elsewhere as ‘the first commercial enterprise launched to apply engineering principles to synthetic biology’).

The BBF had about 400 members shortly after its founding. Describing the nature and function of the new BBF, Endy said that its primary goal was ‘to develop and deploy foundational technologies’ that would enable ‘the establishment of an open collection of BioBrick parts’ – in other words, ‘to ensure that BioBrick standard biological parts exist as open-source genetic components that can be freely used and improved’. Endy confessed that exactly how to do this was not entirely clear, but it was a position that he described as ‘derived from consideration of biotech industry’. It was ‘not a religious position’, about being ‘religious about openness and freedom’, but was simply based on the belief that ‘anybody who has constructive intent should have access to constructive technology ... Folks work well together and are more constructive when they tend to share’. This sounded like a good idea, he thought. Getting there would require both technical standards and a legal framework. ‘None of these things make sense without a community’, he concluded. ‘Community sits on bottom and on top of all this’. The Foundation was assisted in its work by attorneys at the Samuelson Law, Technology & Public Policy Clinic at UC Berkeley, and two partners from Fish & Richardson PC, one of the nation’s top private biotech firms based in Boston, whose initial pro bono work representing the BBF had the specific focus of drafting a public BioBrick™ license. (The work would later be completed by the firm of Duane Morris LLP.)

The BBF ‘tends to accumulate responsibility’, Endy noted, as it had already become the institutional organizer of the flagship series of synthetic biology conferences, and yet, ‘if I had my druthers’, Endy noted, ‘it would have a limited set of responsibilities’. He envisioned the Foundation as more akin to the Free Software Foundation – far away from ultimate products – than the Recording Industry Association of America. ‘I think that’s a possibility – another organization could be developed to do that’, Endy noted, but ‘it’s not why we got started to create that kind of marketplace’.

At the advice of the internet guru Dave Clark to hold a meeting with ‘a boring title so that most people won’t come’, Endy had organized the first BBF workshop in 2007 to discuss the IP dimensions of his vision of a new Registry. He began the meeting by saying that he had just had a long discussion with Clark and received a ‘tremendous, authoritative run-through of technical standards in the internet world’, learning about the variety of legal mechanisms available to the nascent Registry. ‘I’m still sort of horrified by all the lessons that come from that’, he began, ‘and how it took them about five years to struggle through the decoupling of TCP and IP [transmission control protocol and internet protocol] to eventually put together a communication platform that was much more valuable’. He held that it was crucial to be clear about the boundary between the BioBrick part and the product and ‘get a real crisp description of what we want these two classes of objects to be’.

An essential ambiguity remained, however: one person’s product could become the next person’s base part. One European participant proposed that any device made of BioBricks be returned to the Registry to be again considered a Biobrick – in other words, that an ‘infective scheme’ could be developed to protect BioBricks. But Endy questioned such a move: ‘This is
where I wonder if we couldn’t pull off a hack, have a different way to think about the framing, the decoupling, of the different parts so that we don’t fall into the trap of all fouling up the abstraction hierarchy’. The same issue that had dogged questions of technical standards reemerged as a legal question: what if today’s product were merely tomorrow’s part? How could IP be applied in such a situation that would preserve the openness of the Registry and its potential for growth? ‘Is there any way to get off the abstraction track in terms of ownership?’ Endy asked. One participant responded: ‘it might be dangerous if we find such a hack; any hack can be used against the whole thing’. But Endy clarified further, citing the distinction between a finished product and how the genetic information was contained within each product – he gave fictional examples of an anti-malarial pill, and a new self-replicating purple fungus that might prove popular as a ‘lawn ornament in New Jersey’. Endy thought that there was room for both of these two notional classes of products in the system: one product that had the source code and the parts ‘still inside’ and physically instantiated, as well as one like ‘a drug or chemical or material produced from a biochemical system’. ‘I think we want to allow for both’, he concluded, but ‘I don’t know that there would be a material difference in how the legal mechanics played out’.

Rettberg then proposed three options: that all uses of BioBrick parts be free and open to anyone, eliminating all issues of hierarchy and location; or that the parts not be free but unable to be used in ‘New Jersey’ (an example of location-based restrictions, as with patents); or that payment might apply to all users, with an ‘entire structure of rights, rights management, paying, banking, some financial structure that pays rewards to the people who did the work’ – not only the last person, but even ‘including the guy who was in some iGEM team so many years ago. I kind of think “all BioBrick parts and their uses is free” is a better answer’, he concluded.

Endy wasn’t convinced that these were the only options, and proposed an even more radical solution: ‘It might be that we have to reboot ownership of BioBrick parts …. Even though we have a couple of thousand parts in the collection, they suck sometimes. Starting over with an IP-free collection would not be an infinite amount of money’, and one could devise different ways of rewarding people to contribute, although certainly some would want ‘to give their parts because they feel there’s a platform being built’. In struggling to propose the best path forward, Endy often vacillated between the dynamics of a norm-driven moral community and an economy of IP rights, and was conscious of the divide: ‘I’m not sure I want to cut that too finely’.

Concerns were also raised at this early workshop about the reverse-engineering of a product that could lead to other products not at all dependent on BioBricks. One venture capitalist, Talli Somekh, responded that such things undoubtedly happened in the early years of the internet: ‘People, were probably stealing code left and right until industry, and enough people, began to understand the benefits of free software …. We’ll have to bootstrap ourselves till we have enough people that get it’. Operationally speaking, this seemed to imply that it would be okay for people to ‘steal’ from the system. But another participant, uncomfortable with this conclusion, wondered aloud:

As a group of scientists, how are we going to compete at present with our moralistic ideals in a legal context? We can’t file patents. I’m not a lawyer, and don’t have that much legal understanding. But the big biotech companies have the finances, can go to
court, file patents, protect licenses, all the IP stuff. We can be the greatest people in the world, but how then do we stop people who want to make capital, who want to make businesses? How do we allow this moralistic view of the world to exist?

Endy agreed that ‘yes, we are just a bunch of underfunded academics’, but he held that ‘we’ve already been involved – many, if not all of us – in dramatically … in starting a process that is changing the world. We’ve already started and we’re still going’.

Another participant noted that he hoped the Registry would have well-labeled parts that were ‘IP-free’:

There’s a lot of parts in the Registry that are known to not be IP-free, known to be encumbered, to not be legally usable in products or legally usable at all so as a community we don’t actually have choices when we approach the Registry because we haven’t… [sic] it’s true there’s a problematic fact [that] the world is full of people who all want to use or build free parts or to patent free parts every chance they get. Maybe we can start by labeling.

Although others have reported that Endy had already estimated in late 2006 that ‘about one-fifth of the biological functions encoded by parts of BioBricks are already covered by patent claims’ (ETC Group, 2007, p. 33), Endy chose at this point in the meeting to remind the group that his vision was for the entire pool of BioBrick parts to be ‘completely free’.

He also sought to clarify something not entirely evident up to that point: that the BBF and the Registry of Standard Biological Parts were ‘not the same thing’. Although he noted that the BBF has as its goal ‘supporting an open collection of standard biological parts’, he was indifferent as to its actual location: ‘Whether or not the Registry exists at MIT, eh. If we have to make our own Registry we will: the BioBricks Registry. I hope we don’t have to do that, but if we need to, we will. It’s important to recognize that these are two different things’. Almost reflexively repeating the engineer’s mantra, he concluded: ‘Decoupling is important’.

Despite a lack of clarity on just how to proceed, an emerging vision of what would one day become Endy’s vision of a ‘bio fab’ were already clear:

No … current company really understands what a synthetic biological part is, let alone producing a collection of synthetic biological parts and nothing even resembling a sensible or fantastical business plan [exists] that would enable investment to drive the collection of such an investment project. I hope to see one someday, but as yet no… we’ve got first-mover advantage. There happens to be this other community, iGEM, which appears to be growing exponentially, that is based entirely on BioBrick synthetic biological parts, and that’s very informal. We want to continue to support that community and not mess up as a partnership. [It’s] a really nice network of parts producers, distributors, and users, [but I can envision] parts of factories supported by public investment.

Somekh joined in: ‘the only thing that we [venture capitalists] really care about is making money. If you can show that we can make money better, faster, cheaper, looking at cheap parts, we would do it’. Endy felt that there was ‘a bet really that is being placed if you’re participating in the BBF: we’re actually going to be able to deliver on the technology, and that doing it openly is better. And if you don’t believe that you should go try and do it in a
different way. My personal idea … is to do biotechnology on a scale never been done before’.

Endy began the conversation on the second day of the November 2007 workshop by asking whether a hard ‘share-alike’ provision or viral clause was an important feature of a BioBrick™ license. He gave the famous example of the iGEM team of undergraduates that over the course of a summer in 2006 reworked the aromatic bouquet of *E. coli* to smell like wintergreen while growing and bananas while resting. Such a project required pulling together 24 different BioBrick™ parts, Endy noted – or rather, 24 separate pieces of DNA and six different genes encoding enzymes, six different coding sequences and a BioBrick™ inverter off the shelf for a regulatory function. ‘Now who owns all these parts?’ he asked. ‘It’s not really clear because we haven’t looked into it that carefully’. The parts had been donated by researchers at other schools, or were at least freely shipped, Endy noted. Because this was a summer project with undergraduates, the timing of the project meant that the pieces were ‘being deployed faster than we could really afford to sort through the ownership framework, to do due diligence, to do licensing, etc.’.

Endy wasn’t opposed to patents in principle – there was nothing religious about his stand, as he had put it – but he had done ‘a lot of initial work studying the landscape’, determining ‘what are our legal options … patents, copyright, contracts, public domain, or something sui generis’? Drawing on his work with the Center for the Public Domain at Duke Law School, Endy then proceeded to outline the strengths and weaknesses of each of the several options for the BBF.

He concluded that ‘patents have the feature of being accepted standard practice in biotechnology research’, although his own view was that ‘they’re slow and expensive’. To file for patent protection on every one of the 800 new parts in iGEM that year would cost an extraordinary amount: ‘If I could get that money I’d not spend it on the patents, I’d spend it on making new parts that are better’. Copyright, by contrast, he promoted as ‘cheap and easy to use’. He noted that other organizations had already pulled off ‘some very impressive legal hacks’ using copyright ‘that have enabled free software to promulgate’. Copyright seemed like a useful legal mechanism for BioBricks, and already he could envision ‘an interesting hack you could pull off with copyright’ for the purposes of synthetic biology:

could you copyright standard genetic parts? It could be pretty appealing to us. It scares the heck out of certain academic lawyers. But if you misfire, the consequences of success could be very bad, because copyright has a very long persistence time, thanks to Mickey Mouse …. If someone else took what we did and deployed it for purposes against our own it could have long-term failure costs. It’s also not the accepted use today [for biotechnology] and you’d have to argue to the federal judiciary that the synthetic biologist is a genetic poet, and that when I speak in ATGC, I’m an artist. Which is obviously true, but we’d have to go win those arguments.

Laughter filled the room.

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8 Although this was not shown at the workshop, much of the discussion overlaps with Endy’s PowerPoint presentation: ‘Open Biotechnology & the BioBrick Public Agreement’, http://openwetware.org/images/f/fd/Why_the_BPAv1.pdf.
Endy rapidly dismissed the contract model, so common to earlier historic forms of IP protection (especially among breeders and seedsmen before the twentieth century), as essentially ‘leaky, defined agreements’. And so it was finally the public domain model that Endy was most intrigued by: ‘that’s sort of what we’re using; I guess it’s what we’re using right now well, we’re sort of providing some sort of public dissemination of this information. We’re not formally signing a declaration’. The problem with this approach still, Endy realized, was that ‘someone could go to the Registry, take all the parts, write a computer program that would assemble the parts in novel combinations, physically construct them, screen them for use, and then file on the ones that are useful’. The immediate consequence of this public domain approach was, he noted, ‘it might not be strong enough as a legal strategy in the context of building a community with the goal of being able to rely on BioBrick parts remaining open, that you won’t be screwed by somebody else coming in later’. He also considered further _sui generis_ options that would create forms specific to the domain of protection (reproducing machines with genetic material), or ‘maybe we could just invent some new legal framework for BioBrick parts, or synthetic biology more broadly …. It could take a while, it could be expensive, it could be political’. Would this be done over or under the table? Would it be easily implemented as a new piece of law? Or would it all go ‘horribly wrong at the last minute when it gets attached to the food bill, or messed up attached to farm subsidies or trading’? He concluded ‘it’s not completely worked out – the long-term strategy is still being worked out with respect to BioBrick parts’.

Comparisons were frequently made to the open-source software movement, which existed in a large academic environment where sharing was a norm, and which was said to be distinct from industrial environments like IBM where everything was claimed to be a trade secret until the extension of copyright to software in the late 1970s. The free software movement, by contrast, was said to claim ownership of its creations in order to make them available under particular licensing terms. According to Endy, ‘early licenses at certain points disallowed commercial use of the code, and those were purposely removed in order to allow the development of a product-based industry on top of the code’. He saw promise in such an approach – a HistoryBrick here worth holding onto. The more recent emergence of skirmishes over the potential application of patents in the software world also demonstrated to him, however, that far from being a dead and static thing, any successful legal framework would depend on ‘a community that decides to defend it or not’. Whatever legal solution to the IP problem emerged, he noted, ‘if nobody wants to recognize that or use it, then it’s useless – so you need to have a collection of the community and the legal framework’. Endy also wondered whether BioBrick™ parts – ‘because we are part of a living world and depend on it’ – might be a special case involving concepts of ‘freedom’, a concept he would later return to.

After two days of extensive open-ended nondirected ‘amazing conversations’ at what he considered ‘very impressive as a first workshop’, Endy concluded: ‘I’d like to declare success …. The framework needs to be refined a little bit, but we have, speaking for myself, gotten much better clarity in what we might want in terms of BioBrick™ standard biological parts and technical standards that need to be developed’.

By the time of the Synthetic Biology 4.0 meeting in Hong Kong in 2008, however, with many of these questions still not fully resolved, matters seemed less impressive. During a session on IP oddly focused mostly on American law, a simple question from a venture
capitalist about the best possible way of organizing the open-source infrastructure and about the ‘legal relationship between the repository and the individuals who supply that repository with parts’ led to some head-scratching. ‘That’s something that we’re working on’, BBF consultant Dave Grewal responded, saying that multiple modes could be imagined. ‘The idea that BBF has to have the one answer for the whole field is not at all clear’. But in general, he felt, echoing the statements of the earlier workshop, ‘the more you can move lawyers out from the main action, the better’. With J. P. Morgan’s maxim that ‘I tell the lawyers what I want to do, and they tell me how to do it’ also having been tossed into the discussion, Grewal concluded: ‘We’re going to make something happen here, and the lawyers are along for the ride’.9

**Industrializing: From BioBricks™ to the BIOFAB**

Endy, too, had faced his own criticisms from the clash of open source and IP considerations. As one of the cofounders (along with George Church, Jay Keasling and Joseph Jacobson) of Codon Devices in 2004, it was not entirely clear to some at first how to square Endy’s desire for an open-source biology with his personal commercial interests. Codon Devices was reported in 2007 to have ‘an extensive patent portfolio (63 patent applications and 22 issued patents as of late 2006)’, and the company’s stated IP policy was to ‘aggressively pursue patent protection for most of our proprietary technology, and protect other aspects of our proprietary technology as trade secrets’ (Rai and Kumar, 2007; ETC Group, 2007). One conference participant told me that he wanted to scream out ‘Codon Devices!’ to Endy at one point during an extended exchange on the meaning of ‘openness’.

In fact, by the time of the BioBricks workshop in 2007, Endy publicly declared that ‘I may have to reexamine my current position at Codon to take this work. I need to rethink my own relationships, but it might be that this is different somehow, and that’s because if we want industries to grow up around this we need to figure out that connection’. (Pam Silver also suggested that it was common for a company to have a ‘foundation arm dedicated to giving money to other foundations’, and so there need be no inherent contradiction.) After spending its way through more than US$33 million in start-up funds, Codon Devices ultimately closed its doors in early 2009. ‘Codon crashed and burned wonderfully’, Endy told *The Wall Street Journal* (Hotz, 2011).

The role of IP considerations in iGEM also remained unsettled – as did the exact significance of iGEM in the emerging synthetic biology community. Rettberg had thought it was an ‘extreme error to think of iGEM as a teaching program where a synthetic biologist teaches the students how to do synthetic biology’.10 Although the iGEM competition was

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9 Stephen Maurer added that, ‘this is exactly about keeping Microbesoft from emerging as monopolist in synthetic biology’, and said that ‘there is a left coast and right coast way of doing these things’. It was ‘very important’, he felt that ‘once you have a program to build an actual open-source thing out there that you do this very very openly as a way to demonstrate to the world that you don’t have actually a crypto-antitrust scheme out there, and that is a way to structure this debate’.

10 Such stated intentions apparently did not reach an audience member at the May 2011 Bio:Fiction event at the Naturhistorisches Museum of Vienna, who asked: ‘so is iGEM like Suzuki method or a new science methodology?’ or Craig Venter, who announced to a large audience at LSE in 2008: ‘Biobricks are sort of a student project and it’s fun and there’s a lot of discussion around it’.
certainly instrumental in helping to develop some new BioBricks, Richard Kitney of Imperial College publicly stated in 2009 that ‘we shouldn’t hide behind the fig leaf of the iGEM competition’. What was needed was to take synthetic biology ‘up to the professional level’, and he felt that there was ‘a common view on how to proceed in this area’. Kitney argued first for the creation of an ‘open-source professional registry as opposed to the MIT one, for iGEM’ and he considered this a basic part of the research infrastructure in synthetic biology for universities and research institutes, with materials available to access free of charge. At the ‘next level’, he indicated, further commercialization could take place: ‘When commercial companies want to use the parts for commercial products, they can do this and take the parts and ... patent ... and sell them .... They may well be charged money to access the parts’. As another member of the panel chimed in: ‘everyone gets to play with the Legos™, but if you make something interesting …’.

Kitney was not the only one suggesting that the time had come to move beyond the Registry and to talk about the commercialization of parts and the attendant IP concerns that this would raise. Although Endy had never explicitly spoken against the Registry, he noted that, ‘We now need to move beyond Lego™ metaphors and genetic toys to professional technologies’. When he left MIT for Stanford, Endy effectively left the Registry of Standard Biological Parts to pursue his dream of a biology made ‘easier to engineer’ through the use of standard biological parts, this time through calls for the creation of a ‘bio fab’ – a novel pursuit of the BioBrick in industrial form.

Founded in 2009 with a 2-year $1.4 million grant from the National Science Foundation, in cooperation with the Lawrence Berkeley National Laboratory and the BBF, Endy characterized his new BIOFAB (the recursive GNU-like acronym now standing for ‘BIOFAB, International Open Facility Advancing Biotechnology’) – as an attempt to create the ‘open technology platforms underlying and supporting the next generation of biotechnology’, by producing ‘thousands of free, standardized DNA parts to shorten the development time and lower the cost of synthetic biology for academic or biotech laboratories’. For all of iGEM’s success in developing the field and building international connections, Endy was out to create nothing less this time than a fully professional enterprise with nearly 30 employees to fully characterize ‘parts’ in *E. coli* and *S. cerevisiae* for industrial use, and by focusing on gene expression and successful protein synthesis rather than DNA sequence alone. The new enterprise was to be a ‘factory for making very-high quality standard biological parts and giving them back to the community, complementing things like iGEM’. Such statements meant that he would hardly be reinventing the process from scratch. As cofounder Adam Arkin has noted, ‘There’s certainly going to be a great deal of borrowing of what really worked for the [iGEM] registry’ (Katsnelson, 2010). Just what pursuing the dream of an open-source biology by...
standardized biological parts in a new form meant for IP considerations, however, was still unresolved. Indeed, many of the members of an early ‘Bio Fab group’ who described themselves as ‘friends, colleagues and sometime collaborators’, and some of whom were again collaborating in producing the BIOFAB, were also involved with Codon Devices.

**BioLiberty: The BPA**

Although the question ‘this is not a proprietary operating system, is it?’ had drawn audience laughter at the Synthetic Biology 2.0 meeting at UC Berkeley in 2006, by the time of the 5.0 meeting at Stanford in June 2011 IP issues were regularly emerging concerns in many conference presentations and coffee-break conversations.\(^{14}\) While at the 2006 meeting it was a rare thing to hear the question ‘What IP system will deliver synthetic biology’s benefits to the most human beings over the next fifty years?’ by the time of the 2011 meeting such matters of IP had become central to many discussions.

One audience member spoke during one Q&A session at 5.0 to what he saw as ‘a massive gap between academic research and solving real world applications. I look at everything here and it’s like being a kid in a candy store – I want to use that and that and that. But then I immediately thought after that that I’m not going to because the licensing … to get that technology … to be freely available is not worth the effort’. Another participant similarly asked a group of government funders of synthetic biology about the potential for IP reform with respect to synthetic biology, only to be met with a flurry of dismissive waving hands and the refrain: ‘That’s above our pay grade’. IP issues were constantly emerging, as when a speaker from Gingko Bioworks, Reshma Shetty, presented on her new industrial processes, and Tom Ellis (a synthetic biologist at Imperial College London) tweeted that her talk was ‘nice … without giving away all the juicy IP’; or when Chris Newman from Amyris began his talk with a slide containing a ‘safe harbor’ summary and ‘forward-looking statement’ disclaimer. For all the intense interest speakers, moderators and the audience showed in IP issues surrounding several talks, it seemed curious that a session entitled ‘Interacting with Society’ (which had only been organized the Friday before the conference) contained no mention of IP. This was all the more curious given that the BPA went into force that same day.

Presented to the community in its final ‘live’ form on 17 June 2011, the first version of the BPA dated back to 18 October 2009. An updated version, presented 3 months later, was ‘based upon the contribution of promises not to assert any property rights against users of so-contributed standard biological parts’. Ultimately, the BPA effectively

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\(^{14}\) According to Rob Carlson, the 1.0 meeting ‘had a very academic feel’, while the 2.0 had ‘an interesting new flavor, namely that of money’. The 5.0 meeting, in contrast, was saturated with talk of IP (Carlson, 2006).

\(^{15}\) Reshma Shetty responded: ‘It’s always a challenge for us. We are very invested in promoting community around synthetic biology’, noting that Gingko Bioworks would soon be contributing parts under the BPA, ‘but at the same time to, [sic] in order for us to make a living and continue to do the things we want to do, we have to build a sustainable business’, she said with a shrug. ‘So we kind of trade-off. We think it’s really important to foster an open collection, but there are other aspects of our pipeline that we’ll be keeping proprietary’. She characterized it as a question of making ‘intelligent trade-offs, where the community will draw the most value from what we have to contribute’.
attempted to insert a moral economy into a bilateral contract for material and informational transfer. This juxtaposition with an open pool was presented not as a mere alternative to patenting, but as a novel displacement of the IP arrangements typical to contemporary biotechnology.

Moving away from a gift economy enforced solely by social norms of sharing (common in early classical genetics, for example) while still attempting to avoid the threat of patent thickets so common in contemporary biomedicine, and yet not going as far as a viral or infective license that would contain give-back or share-alike provisions as some had proposed, the BBF’s BPA attempted to carve out both a commons and a realm governed by bilateral contract, all the while preserving what amounted to a novel continuation of an earlier historical tradition of ‘breeder’s privilege’ – that one can continue to use the standard parts at will to keep on tinkering to produce new things. The breeder’s privilege now, however, was plural. Endy had sought and seemingly succeeded in creating a quasi-contractual mechanism for providing a ‘research exemption’ and for avoiding a patent thicket, while permitting the industrialization of an engineered biology based on standard biological parts – whether these would be part of the Registry at MIT or elsewhere, as in the new BIOFAB. In this sense, the BPA was entirely virtual.

The final version of the BPA, completed with the pro bono help of Mark Fischer from the firm of Duane Morris LLP and several others, instituted an IP structure that was inspired by – but different from – GPL. (Fischer had in fact worked earlier with Richard Stallman at the Open Software Foundation.) It had no viral or give-back requirement and thus was not a form of copyleft, and yet was also not a form of patent, copyright or a material transfer agreement. It was a carefully synthesized legal entity predicated centrally on a promise of non-assertion, with ‘the promise of giving something and not being liable for either being a contributor or a user’, as Fischer noted.

Demonstrating the new BPA website (http://biobricks.org/bpa/) at the 5.0 meeting, Endy clicked on a button labeled ‘get your freedom!’ that enabled users to sign on to the agreement and to ‘use your parts’. Endy characterized the new BPA as enabling a newfound freedom from otherwise time-consuming and potentially expensive freedom-to-operate analyses – the process of determining whether one’s desired course of action was unconstrained by IP concerns – thereby bringing about for the first time in synthetic biology what he called ‘BioLiberty’. The effort had taken a couple of years, and, although Endy may not have been a lawyer when he started, his having ‘spearheaded’ the effort meant for Fischer that Endy ‘has certainly earned his legal degree to add to his other talents’, as Fischer announced to the conference assembly. IANAL, indeed!

And so a curiously fractured IP situation has descended upon the synthetic biology of BioBricks at the current moment: many of the parts in the MIT-based Registry of Standard Biological Parts are highly unreliable and more than six different ‘standards’ have been proposed and yet a flawed original standard is still the most commonly used among iGEM teams, with no IP protection for any of these parts being retroactively covered by the newly released BPA, although some of these parts are in fact already patented or otherwise encumbered; the major users of the largest registry of parts are undergraduate students competing in an annual competition, with relatively few practicing non-adolescent synthetic biologists making use of it, and yet the Registry is repeatedly upheld as the symbol and future for open-source biology, most especially by
outside commentators and scholars seeking to investigate, analyze and understand the phenomenon of synthetic biology, and who assume its imminent industrial impact; the Registry continues to have closed-source code, even though Rettberg has left MIT, and a number of open-source competitor registries are now available in an ever-expanding and potentially hyperlinked web; the ontological, empirical, technical and legal status of many items contained in these many registries and repositories remains largely unclear; Endy’s newest effort to create a collection of standardized biological parts through the BIOFAB has no particular institutional connection with his first efforts and the standards of the Registry (as he had suggested, ‘Starting over with an IP-free collection would not be an infinite amount of money’), although some interaction with iGEM is foreseeable and intended and the BPA may work for both collections; Knight has initiated a new foundational tools scheme at Gingko Bioworks, also largely leaving the BioBricks framework behind; and the degree to which private corporations will participate in the BPA remains to be seen. Dramatically, then, none of the three early major figures in the standardization of biological parts discussed here – Knight, Endy and Rettberg – are continuing to work with BioBricks in the same manner in which they began. And yet, the BPA has just been released, the 6.0 conference has just been scheduled for June 2013, rhetorics of the democratization of synthetic biology continue to be carefully (and not so carefully) deployed, and, perhaps most strikingly, the relationship of the BPA with the already extant IP policies of UC Berkeley, Stanford University and the Lawrence Berkeley National Laboratory – all involved in the BIOFAB – remains unclear. The relationship between synthetic biology and IP concerns is clearly still in flux.

The intense interest devoted to BioBricks by many practitioners in these early years of synthetic biology simultaneously rationalized the investment of time, effort and resources in the pursuit of ‘BioBrickiana’ all the while further increasing the bubble.16 This is perhaps not so different from the interest many social scientists and legal scholars otherwise generally unfamiliar with synthetic biology have now begun to devote to ‘the case of BioBricks’. Entranced by the admittedly entrancing idea of BioBricks and the possible legal devices that one might attach to them, however, both synthetic biologists and ‘parasynthetic biologists’ might well consider whether the BioBricks bubble has already burst, and whether other sites of emergence of IP concerns in synthetic biology are now more timely or compelling. After all, the emergence and development of IP in synthetic biology is not separable from the discourse, norms and actual ecology of practices that characterize the field, and BioBricks are but one part of this much larger field.

Rather than assembling insights solely from ex post facto published accounts, employing (merely) logical assessments of likely futures, and paying attention to only one particular subset of a vast realm of synthetic biology work, it seems eminently worthwhile to include greater empirical detail and complex contingent particulars in our accounts as aids to further analyses. It is only by attending to the specifics and to the possible pluralities of meanings uttered and debates engaged in, that we can best trace the emergence of views over time, relate them to their contexts, and understand the novel formations and movements of IP concerns in synthetic biology. The road stretches before us.

16 I am indebted to Mario Biagioli for this formulation.
Acknowledgements

An earlier version of this article was first presented at a Workshop of the Centre for Synthetic Biology and Innovation (CSynBI) on ‘Synthetic Biology and Open Source: Normative Cultures of Biology’, organized by the BIOS Centre on 23–24 September 2010 and funded by the UK Engineering and Physical Sciences Research Council.

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