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Introduction: the cut that makes a part

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Introduction

The contributions to this special issue explore some conjunctions between synthetic biology and intellectual property. For the most part, practitioners of synthetic biology frame these conjunctions instrumentally, in terms of how law might facilitate science: How might one draft a commodity constitution that fosters an ethos of openness, builds community, and advances the conceptual agenda of biology, while at the same time, perhaps, allowing as much commercial appropriation of community goods as might be necessary to realize the industrial potential of the new science? These terms of engagement stake out lthe aw as the medium or terrain of a contest over the ethos of the biological sciences. Much terrain has already been lost to the 'neoliberal programme', whose basic objective is 'to decouple most functions of scientific research from the educational functions to which they had been wedded during much of the twentieth century' (Mirowski, 2011: 37), but the gamble in this case is that because legal instruments are just that – instruments – they might be turned to the task of fashioning a constitutional framework for open science. One implication of this strategy is that the artefacts of synthetic biology will have to take on shapes that are adapted to the shapes into which legal forms and instruments might themselves be engineered. The engineering of life is bound into the engineering of law, and the ambition in both cases might be radical reinvention: 'If we're rebuilding the living world we might have to expect rebuilding part of the legal system (Drew Endy, cited in Campos). Our contributors reflect on the ways in which notions such as closure and openness, part and context, or materiality and information, are mobilized in the formulation of this strategy for the mutual engineering of biology and law. On the other side of the conjunction, it may be that the synthetic biologists' project of reengineering life can tell us something about the latent states of intellectual property regimes.

The historical and contemporary contingencies of intellectual property have only begun to be properly explored by social scientists (for such a beginning, see Biagioli, 2006). Critiques of intellectual property tend to bring to private law what Michel Foucault (1977) called the 'repressive hypothesis' of power. That is, they assume that technical forms and institutional decisions describe their own agency in the world, so that to have an intellectual property right is necessarily to have something like the powers of control and exclusion that lawyers ascribe to property. In fact, intellectual property is just a cipher for a set of propositions, techniques and strategies that have been turned into an effective ideology by more than two centuries of legal and economic commentary. Legal forms and decisions have effects, but the right place to begin in developing a social-scientific account of those effects is with the 'knowledge practices' (see generally Riles, 2011) that are proper to law.

Our contributors outline some of the knowledge practices at work in synthetic biology, and how they shape the apprehension of the threats or possibilities of intellectual property. Stephen Hilgartner contrasts the ideology of 'innovation discourse', which treats decisions about the acculturation of technology as external to the intellectual property domain, with a 'politics of technology' perspective that introduces 'democratic choice and problems of political representation'. Jane Calvert explores the performativity of 'informational metaphors' in the fabrication of patent rights in biotechnology and synthetic biology. Chris Kelty holds the synthetic biologist's sense of openness up to the light of a modern archetype of open collaboration. And Luis Campos keeps an ethnographic ear to the ground in telling the story of how intellectual property questions 'were actually hashed out' within the synthetic biology community.

How might synthetic biology's normative strategies stir up our understanding of intellectual property? Following the example of the open source software movement, some synthetic biologists seek to mobilize intellectual property forms as something other than instruments of economic interest. We should not overstate this point. Stephen Hilgartner notes that the basic normative goal of the BioBricks Foundation initiative is 'technological progress, augmented with the goal of supporting freedom to create'. This is not immediately divergent from the goal that is conventionally ascribed to the patent system. And, if we turn our attention from semantics to technical media, the orientation towards an economy of innovation becomes even more evident. Adrian Mackenzie observes that the formulation of synthetic biology as a software-based design practice turns biological work into 'a process that is no longer primarily concerned with experiment and knowledge production, but with the organization of work, production and innovation' (2010: 189). Nonetheless, following Hilgartner's and Kelty's lead, we might take the emergence of the BioBricks Foundation's project as a constitutional moment precisely because, as Hilgartner puts it, synthetic biology might have 'the ultimate effect of reducing the number, scope, strength, and strategic significance of patents and thus producing less concentration of configuration power'. Or, as Kelty has it, synthetic biology may figure a kind of in-between moment: 'the novelty of synthetic biology lies not in its claims and object but in the fact that it sits at the intersection of two different—and conflicting—systems of managing that creation of novelty'. The question then is whether this constitutional moment might yield some interesting variations and complexities of legal form.

Repartition

As Stephen Hilgartner observes, empirical questions about the effectiveness of the Biobricks Foundation regime 'are most readily posed in the future tense'[1], but it is also true that there is no singular target against which to measure 'effectiveness' when that future is reached: 'there is no immediately obvious pattern, uniformity, or singular orientation toward IP issues in synthetic biology' (Campos). It may be, however, that the complexities of the encounter between synthetic biology and intellectual property constellate around a basic question – *what is a part?* The exercise of trying to engineer standardized biological parts reveals the diverse modes of repartition of processes or networks of scientific research: there are legal, economic, technical, and political ways of realizing 'parts', 'shares' and 'contributions', so that what is initially presented as a technical exercise in engineering turns out to be an exercise in configuring these diverse idioms and techniques of repartition.

It is obvious to synthetic biologists that the cut that makes a part is as much normative as it is technical. There are fundamental technical challenges in characterizing and bounding parts. What should one do about scar sequences? (see Ellis, Adie & Baldwin, 2011). How should one reconcile material form (specificity) and functional form (information)? How might one engineer contexts out of (or into) standardized modules? (Bennett, 2010) But there is no way of phrasing these questions that does not of itself betray the implication of these technicalities in normative cultures. As Jane

[1] There is a sense in which synthetic biology has taken shape as 'future perfect science' – as distinct from 'fiction science'. 'Fiction sciences [are] extensions of existing technology. They can be viewed as scientific with a high degree of plausibility and most scientists would agree that, with sufficient funding and research, such technological feats are feasible. The general path on which to reach them is already somewhat clear' (Baldi, 2001: 2). The future perfect tense is that of 'what will be the case when….'

Calvert observes, both of the leading variants of genome engineering are committed to the modular vision of life. For those involved in the BioBricks Foundation and associated initiatives[2], the task is to create biological parts that have been 'engineered to meet specified design or performance requirements' (Canton, Labno & Endy, 2008), and, more broadly, to actualize untapped potential by (re-)instrumentalizing biological processes. In parallel, the object of the Venter Institute's 'synthetic genomics' is to engineer a standardized and fully characterized genomic chassis into which one might insert alternative genomic 'cassettes', with a view to turning cells into metabolic factories. In both cases, the aim is to create components with attributes of stability, reliability and interoperability that would make them the de facto industry standard, but each enterprise has its own proprietary strategy. Synthetic Genomics pursues the patenting route that could grant it a rare degree of market dominance. The counter-move of the BioBricks Foundation is to turn modules into democratic rather than monopolistic standards. Although the strategic use of trademark law to index and retail the technical quality of BioBrick™ components might give its standardized parts a certain market aura, this effect would be used to facilitate the adoption of standardized parts by users who were committed to the project of engineering biology from an open source collection. These are two kinds of normative framework for the ethos of biological sciences.

As Chris Kelty's history of the *Drosophila Information Service* makes clear, there is a difference between the normative and the legal. This specialist scientific newsletter articulated senses of property and propriety that were quite consciously differentiated from the formal precepts of copyright or patent law. It was a vehicle for negotiating the relation between the researchers' senses of individual property, or 'the research and intellectual activities of an individual or lab', and collective property, or 'the concepts and techniques that are necessary to coordinate research in order to produce a complex object like a map of chromosomes'. In trying to make these senses explicit through work on the medium and content of the newsletter, participants were negotiating the question of where to draw the two constitutive boundaries of a scientific 'moral economy'. 'Rules' about such things as the scope of the duty to share materials, the difference between a 'resource' and a 'result', or about what counted as proper attribution, at once drew the boundary between individual researchers and the rest of the drosophila collective, and the boundary between the collective and outsiders who were not 'actively engaged in drosophila research'. The collective was a work in progress, and progress depended on differentiating the collective fund from the contributors by whom it was continually being augmented; in turn, this inner differentiation was possible only given the bounding of the collective by the exclusion of outsiders. Kelty expressively captures this differentiation of inner and outer dimensions in the proposition that the newsletter worked as a vehicle of 'publicization' rather than 'publication'. This is where the question of repartition comes in. The newsletter was a means of defining 'parts' in the economic or ethical sense of 'shares'. For the 'inner' public, it was important to recognize the tangible or intangible contributions made by each researcher to the collective object, while at the same time acknowledging that researchers were also acting on behalf of the collectivity, 'in the service of producing a larger system of knowledge'. 'Parts' in this sense were the products of a process of ethical repartition which balanced the claims of individual researchers against the claims of the

[2] Initiatives associated with the BioBricks Foundation include: the MIT Registry of Standard Biological Parts, the International Open Facility Advancing Biotechnology (BIOFAB), the SBX.0 conference series and the iGEM competition. Although all of these initiatives share the objective of engineering modular DNA-based biological parts, the specific BioBricks™ parts are only used by the MIT Registry and the iGEM competition.

'whole'. So there were two (not necessarily congruent) senses of 'parts' as ethical shares and technical contributions.

What happened to this logic of ethical repartition? From the 1980s onwards, pressures (or incentives) to commercialize university research changed the sense that many scientists had of their contributions to collective research efforts. Crudely, an economy of scientific credit became an economy of price and, in the process, material and immaterial contributions became 'research tools'. In a report commissioned in 1998, a working group appointed by the NIH characterized the situation in terms that have been cited often before, but which are still worth revisiting: 'What counts as a research tool and what counts as an end product thus varies from one institution to the next. Inevitably, each institution minimizes the value of the discoveries it borrows from others, while seeing great value in its own past and future discoveries' (NIH, 1998). There is a kind of collectivity here, identified not in terms of a common resource but in terms of a flow linking 'upstream' and 'downstream' positions. It takes shape as a configuration of 'parts' that are entirely out of proportion to any 'whole'. The effect is to dissolve both of the boundaries that constituted the drosophila collective – the balance between individual and collective, and the differentiation of one cognitive collective from others – and to structure research collaborations or reciprocal dependencies as a deformed multiplicity of overvalued 'parts'. In Kelty's terms, the point is that there is no process of 'constitutive closure' in operation in this economy.

Now, if the organism of choice for studying the old moral economy of science is the insiders' newsletter (see Kelty), then perhaps the exemplary successor to the twentieth-century scientific newsletter is the lawyerly text of a contract, or, more precisely, the material transfer agreement (MTA). The object of an MTA is not to effect a definitive transfer of a 'material' research tool,[3] but rather to characterise it and regulate its uses in such a way as to impose continuing obligations and claim future (contingent) rights. MTAs will often define the 'material' in such a way as to include all progeny, derivatives, or modifications; they might specify that the material should be used for research purposes only and that all 'passport' data supplied with the material should remain confidential; the provider might retain a right of pre-publication review or a right to delay publication of any findings derived from the recipient's use of the material, and many providers will seek to claim a set of 'reach-through' rights in relation to all products or derivatives of the material. The usual forms of reach-through right are rights to royalties in respect of profits derived from the sale of products, rights to royalty-free exclusive or non-exclusive licences in respect of any research tools which the recipient develops through use of the use of the material, and sometimes even a right to full or part ownership of any patents granted to the recipient in respect of 'derivative' inventions. Finally, an MTA might even stipulate that the acquirer keep secret the very existence of the contract. One might say that the MTA is a medium of 'biocapitalist' (Sunder Rajan, 2006) or 'bioeconomic' (Cooper, 2008) speculation, but what is interesting here is the sense in which the contract differentiates (and perhaps diffuses) 'speculation' into a multiplicity of incommensurable positions.

[3] The subject matter of an MTA need not be material in any straightforward sense. Mirowski offers a Borgesian list of examples: 'software, radiology pulse sequences for MRIs, dog food, banks of test questionnaires, psychological assessment protocols, computer chips, absorptive particles in gas masks, plastic polymers, and all manner of machinery used in research' (2011, 156). Still, materiality matters because 'control over physical access provides an easy mechanism for identifying users and imposing restrictions on the dissemination and use of proprietary materials and data' (NIH, 1998).

The emergence of this monetized economy of science highlights a tension that was already present in the old moral economies of science, namely the tension between scientific credit and commercial rewards (Biagioli, 2003). More precisely, it reveals a differentiation of legal form that synthetic biology has to reckon with in attempting to engineer a democratic biotechnology; which one of these legal forms or media is the best vehicle for parts in search of community? Mirowski's observation that the bioscience MTA is 'the IP that dares not speak its own name' (2011: 160) makes the point that the MTA is a distinctive means of enwrapping and circulating scientific resources. The subject matter of a material transfer agreement is defined – or, more strongly, brought into being – by the particular terms on which a contribution is licensed, or by the way that technical potentialities are reconstructed through the negotiation and formalization of reach-through provisions. The legal characterization of the 'part' thoroughly reconstructs its technical ontology. And this mode of reconstruction is different from that of patent law. The basic move of modern patent law is to turn technical artefacts into textual artefacts, or to reconstruct them as material-semantic assemblages that are formed and recombined by the 'physics' that is generated by protocols of interpretation (see Pottage & Sherman, 2010: chapter 7).[4] This is different again from the construction of artefacts in trademark law, where the purpose of the mark is to create reputation goods by relaying the artefact to a particular 'source'. Again, the engineering of modular biology depends on articulating variants of these legal forms into the scientific or conceptual questions that define how a part is addressed to its likely functional contexts: What will be the 'connectibility' of this part with others? To what extent can the (emergent) aptitudes of the part be stabilized to ensure reliable functioning in a range of contexts? What are the proper tolerances of biological engineering?

Re-sourcing

Against that background, how does synthetic biology actually seek to mobilize the potentiality of legal form? A starting point is given by the distinction between normativity and law. Even before we get to the engineering of legal form, the normative project of synthetic biology is already under way. Even if the idea of parts is not necessarily new,[5] the most distinctive feature of the Biobricks Foundation's strategy is expressed in the motto that Hilgartner ascribes to the project: 'if you build it, they will come'. The premise is that if parts are engineered, standardized, and archived in the right way, they will engage the attention of people who will then begin to build with them. Parts are inherently open and democratic because they have been engineered to gather a collectivity of actors around them. A future collectivity is engineered into the specificity and functionality of each standardized part. Perhaps this collectivity will be composed of the people who did this anticipatory engineering in the first place – the roles of contributor and user are themselves seen as modular or interchangeable – but the point is that the collectivity is worked into the initial specification of the part. To turn Langdon Winner's famous question into a proposition, these artifacts most definitely do have politics (see Winner, 1980). This a little bit different from the way that 'parts' were made and construed in the old moral economy of the drosophila collective. There parts were contributed

[4] The same process once involved media other than text (see Pottage 2011).

[5] Bernadette Bensaude-Vincent observes that the idea that emergent processes might be resolved into a finite number of 'unit operations' is already found in early twentieth-century chemical engineering (2009: 8); Michel Morange (2009) sees resonances between the approaches of systems biology and synthetic biology; and Campos (2009) demonstrates how visions of a synthetic engineering-based approach to biology have been a prominent and recurring theme in the history of biology throughout the twentieth century.

to the collective in a kind of recursive movement, which folded individually-generated innovations 'back' into the fund that had facilitated their production.[6] Innovations stimulated and worked with the collective paradigm, but there was nothing like the idea that parts might be engineered in anticipation of a collectivity. The second premise of the BioBricks Foundation strategy is that parts should be the foundational elements of an 'abstraction hierarchy': standardized parts are supposed to be assembled into devices, which might in turn be assembled into systems. Given these premises, how might one seek to reengineer law?

This was, of course, the question that motivated discussion about the drafting of the BioBrick™ Public Agreement. The issue that proved most troublesome emerges from a question recorded by Campos in his ethnography of synthetic biology gatherings. At a meeting convened by Drew Endy in 2007 to consider what might be done with or about intellectual property, one participant asked '[W]hat if today's product were merely tomorrow's part'? What if, in other words, a product derived from an open pool of standardized parts turned out to have the research potential that synthetic biology would like its standardized parts to have? Endy observed that '[a]s 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' (Campos). And, to complete the picture, what if there were nothing to stop the commercial maker of such a product from patenting this derivative product and enclosing a resource that had dropped closer to the bottom of the abstraction hierarchy?

Fundamentally, the question is how to constitute an open and productive resource for science. If the object of open source biology is to generate a collective resource from which further biological concepts and artifacts might be created, this communal fund has to be a 'resource' in the etymological sense of that which restores or renews itself. The collective object has to be continually irrigated, accreted to, enhanced, or revitalized if it is to retain a potentiality exceeding that of the pool of innovations derived from it. The GPL public license produces such a common object by requiring the users of open source to 'return' to the pool any code that iterates any element of the open source code. To the extent that it is used, the notion of modularity has a very different meaning here because 'parts' or 'modules' of code are not bounded in the way that the engineering vision of synthetic biology assumes they should be. In the world of software, the notion of 'modularity' expresses the scalability of tasks: 'each developer decides where and how to contribute, with no formal mandates from those with organizational authority to direct developer labor' (Coleman, 2009: 427). Participants may well have a sense of software as something that has component parts, but this sense is nothing like the normative and technical hierarchy on which the BioBricks Foundation theory of innovation is premised. So the question for the synthetic biology movement is not merely whether it should 'adopt' a viral license such as the GPL, but whether it could do so in the first place given the nature of its commitment to modularity. Hence, perhaps, Drew Endy's equivocation between two positions, one in which he held to the idea that there had to be 'a real crisp distinction of what we want these two classes of objects [parts and products] to be', and another in which he asked whether products might be distinguished in terms of the way that they 'contained' genetic material (Campos).

This sense of modules and their constructability made it difficult to conceptualize a legally-mediated loop of re-sourcing. This may be why, perhaps pending the formulation of a sui generis

[6] Contributions were folded back according to routes which differed depending on whether the part was construed as a results or a resource.

solution, the structure adopted by the BioBrick™ Public Agreement treats the existing BioBricks MIT Registry of Standard Biological Parts as a public access resource, and imposes no obligation on users to 'return' derivative products to the common pool. The strategy is based in part on uncertainties as to the existing ownership status of parts in the MIT Parts Registry – just how many BioBrick™ parts include patented sequences? – and in part on the sheer expense of creating the proprietary bases of a licensing regime. This is how the Biobricks Foundation defined the problem:

> 'There are over 10,000 parts in this repository, and it keeps growing. To patent each of these parts would already cost tens of millions of dollars: if you gave a would-be engineer of biology that much money he or she would probably use it to make better parts. In short, it wasn't straightforward for us to draft something for biotechnology that used the same property right mechanics now typical of software licensing. Once we stopped thinking about a "licensing" approach based on intellectual property rights, we found that a "contracting" approach works better' (BioBricks Foundation, 2011a).

At the same time, however, the strategy reflects a sense that the commercial or industrial uptake of standardized parts would be facilitated by not imposing any obligation on users to make derivative products available to the synthetic biology community. As Calvert observes, at least some of those involved in drafting the BioBrick™ Public Agreement recognized the value of an 'open ecology' of normative regimes, in which 'different forms of intellectual property not only coexist, but also contribute to each other's mutual flourishing'. But if the MIT Parts Registry, or some successor(s) to it, were actually to become the biotechnological equivalent of a set of LEGO bricks, the effect of openness would be to divert most potentially re-sourcing enhancements into the patent system, and so to atrophy what should be the most vital stage of the abstraction hierarchy. If, as Chris Kelty observes, the strategy of synthetic biology is interesting 'because it allows a glimpse into the creation of scientific communities caught in between the need for collective collaborative property in science and the pressures of contemporary intellectual property-saturated biotechnology', then the irony of the BioBricks Foundation's vision is that its radical engineering of a space of collaboration actually makes it vulnerable to the corrupting influence of property.

Prospects

Jane Calvert draws attention to the sense in which both synthetic biology and synthetic genomics draw on 'informational metaphors' in their presentations of the modular vision of life. In the case of synthetic biology, these metaphors surface in the representation of engineering as an information science. The business of synthesizing, characterizing, or assembling DNA is analogized to, or represented as, a process of writing or compiling code. And if the point is to engineer species of biological machine, then the machine in question is 'an algorithmic machine rather than a mechanical one' (De Lorenzo & Danchin, 2008: 825). In the case of synthetic genomics, Calvert traces the analogy to information back to the attempts made by Venter's Institute for Genomic Research to patent whole genomes embedded in 'computer readable media', the idea being that this would facilitate cross-database searches for interesting homologies. And when Venter characterized the newly-made '*Mycoplasma mycoides* JCVI-syn1.0' as a 'synthetic cell', or as 'the first self-replicating species we've had on the planet whose parent is a computer' (Wade, 2010), the adjective 'synthetic' really meant only that the cell's genome was designed in a digital medium (because the genome itself had to be built *in vivo*, using the innate metabolic 'intelligence' of a cell). Metaphors aside, code also plays another role in structuring synthetic biology. As Calvert notes, the projects of

synthetic biology and synthetic genomics are both 'enabled by DNA sequencing and synthesis technologies'. It may be that these technologies will ultimately play the most significant role in realizing the 'parts' of synthetic biology, in shaping the course of innovation in the field, and in framing the conjunctions between the sciences of genome engineering and intellectual property.

The important background phenomenon here is the progressive reduction of the cost of gene synthesis in recent years. The automated technologies that are involved in assembling, correcting and proofreading synthetic DNA are becoming increasingly refined, reliable, and cheap (relatively speaking (see generally Carr & Church, 2009). Earlier accounts of synthetic biology and intellectual property suspected that there might be some trade-off between the vaunted openness of the BioBricks Foundation regime and the opportunities for commercial profit afforded by the demand for gene synthesis (Rai & Boyle, 2007); but the case that prompted that suspicion, namely Drew Endy's involvement in Codon Devices, actually turns out to be the best illustration of what has happened to the gene synthesis market. Codon Devices folded in 2009, for reasons which may not have been exclusively to do with the reduction in value of the gene synthesis market (see Carlson, 2009), but which certainly emphasized the transformation in that market. It has been suggested that the availability of cheap synthetic DNA has become an economic and technological factor in its own right: '[T]he increasing availability of gene sequencing creates more and larger electronic gene databases. This drives demand for protein-expression systems, directed evolution and metabolic engineering, which creates demand for synthetic biology technologies and tools' (May, 2009: 1113). An alternative view is that 'a paradoxical gap exists between our ability to synthesize and our ability to design valuable novel constructs' (Carr & Church, 2009: 1151); or, as Drew Endy puts it, 'can write, nothing to say' (Baker, 2011: 403).

The basic programme of synthetic biology (prospectively construed) was already expressed in one of the first exercises in engineering, namely, the operation of 'refactoring' that was described in one of Drew Endy's first practical papers on synthetic biology.[7] In the case of software, the technique of refactoring involves editing or rewriting code so as to alter its structure but not its performance. In synthetic biology it involves translating or transcribing biological materials into a new medium: 'Without substantially altering any biological function, refactoring readies a specific biological substance for wider participation in processes of design, modification, standardization and experimentation' (Mackenzie, 2010: 190). What is crucial is the question of the medium in which this process of design and modification will take place. The practitioners suggest that synthetic biology will soon be an exercise in computer-aided design: 'Once natural enzymatic and regulatory modules are adapted, refined and measured, they can be combined – at the drawing console – with a high degree of abstraction (ideally with intuitive graphics) while increasingly sophisticated computational methods handle "lower level" steps' (Carr & Church, 2009: 1154). The prototypes for this kind of software platform already exist, in the guise of programs such as *Gene Designer* and *Clotho*, which set out precisely the kind of 'drawing console' that synthetic biologist have in mind. As Adrian Mackenzie notes, the ambition is to concentrate an entire repertoire of technologies into a software interface, each of which might once have addressed 'nature' in the mode of experimentation or provocation, but which now collectively serve as instruments for 'shap[ing]

[7] See (Chan, Kosuri & Endy, 2005: 1): 'A system that is partially understood can continue to be studied in hope of exact characterization. Or, if enough is known about the system, a surrogate can be specified to study, replace, or extend the original. Here, we decided to redesign the genome of a natural biological system, bacteriophage T7, in order to specify an engineered biological system that is easier to study and manipulate'.

things across multiple scales and locations' (Mackenzie, 2010: 183). In such an interface, biological techniques and materials are entirely flattened into a single dimension; the operations transacted in these 'development environments' consist of 'browsing lists of components, cutting and pasting, dragging and dropping components on screen, applying various commands to selected components, and then ordering the DNA construct via a commercial web service' (Mackenzie, 2010: 188).

Calvert points out that the practice of gene patenting was premised on the 'inter-convertibility of materiality and information'. The move is expressed very clearly in a report on the 'ethics' of gene patenting which was published some time ago by the Nuffield Commission on Bioethics:

> Patent offices take the view that extracting the genetic information encoded by a DNA sequence is not just a matter of gaining scientific knowledge about a natural phenomenon: it involves the use of cloning techniques to create an artificial molecule in such a way that it includes much the same genetic information as is to be found in the natural phenomenon. And what is held to be important here is that the scientific knowledge concerning the genetic information has been discovered through the creation of the artificial molecule. That is to say, without isolating and cloning a gene, it is not possible to identify the sequence of bases of which it is comprised. Hence, patent offices have concluded, the genetic information is essentially part of an 'invention', a molecule which is human handiwork, and can be patented as such (Nuffield Commission on Bioethics, 2002: para 3.21).

What is invented and patented is a material molecule rather than the 'genetic information' it embodies. Invention is identified with the material transformation of a natural molecular structure, but this material transformation is also a process of immaterial replication, in which 'information' is transferred from one embodiment to another. The justification of gene patenting played on the difference between – and the inter-convertibility of – material molecules and genetic information, and this sleight of hand was the legal basis of the biotechnological economy. What will happen if or when we have DNA printers that will able to 'print out' designed sequences on demand?[8] When, in other words, will the operative distinction not be between molecules and information, but between the flattened software design and the 'hard copy' (or 'wet copy') printed out by the designer? Of course this is an oversimplification, but the point is that the effect of reconstitution in the medium of software will be to grant what was once DNA a new potentiality. This is not the potentiality that it had *in vivo*, nor even the potentiality that was actualized by the opportunistic interventions of recombinant DNA technologies, but the potentiality that emerges from the digitized medium of synthetic DNA and the sociality that infuses that medium. Perhaps the future for biology and law is indicated by an unlikely convergence of theoretical and practical questions: '[W]here [does] value reside as biology becomes an information science' (Sunder Rajan, 2006: 41)? 'Where is the value? Is it in the design (bits), or in the objects (atoms)' (Carlson, 2009)?

Social science analyses of the knowledge practices at work in synthetic biology for the concomitant engineering of intellectual property and life sciences, of the kind presented in this special issue, are important because they can help us decipher how legal instruments are turned into effective ideologies for both law and scientific research. They can also illuminate and advance public and policy debates about synthetic biology, by demonstrating how discussions of intellectual property that represent the question as a simple dichotomy between 'open source' and 'patenting' strategies,

[8] For a current example of 'bioprinting', see Wired: http://www.wired.com/rawfile/2010/07/gallery-bio-printing/

and assume the choice can be determined independently from progress in producing standard modular biological parts, do not appropriately describe the dynamics at work and policy options available. Social science analyses which is more closely informed by what is actually happening in synthetic biology research could also help us move away from the 'speculative ethics' which currently run through dominant debates about the 'promises and perils' of synthetic biology, described by Nordmann (2007:31) as an 'ethical discourse that constructs and validates an incredible future which it then proceeds to endorse or critique'. Thus an inordinate amount of attention in synthetic biology has been directed to the potential harm that could be caused by bioterrorists with evil intentions or unregulated do-it-yourself biologists; and discussions of these risks systematically start from the premise that an abstract hierarchy of standard modular biological parts *will* be produced that can be easily engineered by anyone with little specialist knowledge or equipment, and that these parts *will* be openly accessible to the synthetic biology community. Constructing the ideology of 'open parts' and 'standard parts' - through legal and scientific instruments - thus becomes inseparable from the construction of incredible biorisks. A more subtle understanding of the propositions, techniques and strategies currently at work in synthetic biology could help us focus instead on more mundane (but no less important) risks and more realistic challenges for the project of synthetic biology.

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References

Baker, M. (2011). The next step for the synthetic genome. *Nature*, 473, 403-408.

Baldi, P. (2001). *The shattered self: The end of material evolution*. Cambridge: MIT Press.

Bennett, G. (2010). BIOFAB Human practices report 1.0: What is a part? At: http://www.biofab.org/humanpractices.

Bensaude-Vincent, B. (2009). Biomimetic chemistry and synthetic biology: A two-way traffic across the borders. *Hyle: International Journal for Philosophy of Chemistry*, 15(1), 31-46.

Biagioli, M. (2003). Rights or rewards? Changing frameworks of scientific authorship. In M. Biagioli & P. Galison (Eds), *Scientific Authorship. Credit and Intellectual Property in Science*, 253-279. London: Routledge.

Biagioli, M. (2006). Patent Republic: Specifying Inventions, Constructing Authors and Rights. *Social Research*, 73(4), 1129-1172.

BioBricks Foundation (2011). Frequently asked questions. Q: Why didn't you want to go for a license like with computer software? At: http://biobricks.org/bpa/faq/

BioBricks Foundation (2011b). FAQ. What is the significance to the ™ symbol (e.g., BioBrick™ standard biological parts)? At: http://biobricks.org/faq/

Campos, L. (2009). That was the synthetic biology that was. In: M. Schmidt et al. (Eds.), *Synthetic Biology, The Technoscience and Its Societal Consequences*, 5-21. Berlin: Springer.

Canton, B., Labno, A. & Endy (2008). Refinement and standardization of synthetic biological parts and devices. *Nature Biotechnology*, 26(6), 787-93.

Carlson, R. (2009). On the demise of Codon Devices. At: http://www.synthesis.cc/2009/04/on-the-demise-of-condon-devices.html

Carr, P.A. & Church, G.M.. (2009). Genome engineering. *Nature Biotechnology*, 27(12):,1151-1162.

Chan, l., Kosuri, S. & Endy, D. (2005). Refactoring bacteriophage T7. *Molecular Systems* Biology, 1, 1.

Coleman, G. (2009). Code is speech: Legal tinkering, expertise, and protest among free and open source software developers. *Cultural Anthropology*, 24(3), 420-454.

Cooper, M. (2008). *Life as Surplus. Biotechnology & Capitalism in the Neoliberal Era*. Seattle: University of Washington Press.

Coombe R. (2003). Works in progress. Traditional knowledge, biological diversity, and intellectual property in a neoliberal era. In Perry & Maurer (Eds), *Globalization Under Construction. Governmentality, Law and Identity*, 273-313. Minneapolis: University of Minnesota Press.

De Lorenzo, V. & Danchin, A. (2008). Synthetic biology: discovering new worlds and new words. *EMBO Reports*, 9(9), 822-827.

Ellis T., Adie, T., & Baldwin G. (2011). DNA assembly for synthetic biology: from parts to pathways and beyond. *Integrative Biology*, 3, 109-118.

Foucault, M. (1977). *Histoire de la sexualité. La volonté de savoir*. Paris: Gallimard.

Mackenzie, A (2010). Design in synthetic biology. *Biosocieties*, 5(2), 180-198.

May, M. (2009). Engineering a new business. *Nature Biotechnology*, 27(12), 1112-1120.

Morange, M. (2009). A critical perspective on synthetic biology. *HYLE : International Journal for Philosophy of Chemistry* 15(1), 21-30.

Mirowski, P. (2011). *Science-Mart. Privatizing American Science*. Cambridge MA: Harvard University Press.

National Institutes of Health (1998). Report of Working Group on Research Tools, June 4th 1998. At: http://biotech.law.lsu.edu/research/fed/NIH/researchtools/Report98.htm

Nordmann, A. (2007) If and Then: A Critique of Speculative NanoEthics. *Nanoethics*, 1:31–46.

Nuffield Commission on Bioethics (2002). *The ethics of patenting DNA. A discussion paper*. London: Nuffield Commission on Bioethics.

Pottage, A. (2011). Law machines. Scale models, forensic materiality, and the making of modern patent law. *Social Studies of Science*, 41(5): 621-643.

Pottage, A., Sherman B. (2010). *Figures of Invention. A History of Modern Patent Law*. Oxford: Oxford University Press.

Rai, A. & Boyle, J. (2007). Synthetic Biology: Caught between Property Rights, the Public Domain, and the Commons. *PLoS Biol*, 5(3): e58.

Riles, A. (2011). *Collateral knowledge. Legal reasoning in the global financial markets*. London: University of Chicago Press.

Sunder Rajan, K. (2006). *Biocapital. The Constitution of Postgenomic Life*. Durham NC: Duke University Press.

Wade, N. (2010). Researchers say they created a 'synthetic cell. *New York Times*, May 20 2010.

Winner, L (1980) Do artifacts have politics? *Daedalus*, 109(1), 121-136.