Ethics of Gene Patenting: Moral, Legal, and Practical Perspectives

By Gabriel Ben-Dor

Edited by Jason Hu, Bryce Bajar, and Julia Borden

Stanford-Brown iGEM 2012

1. Introduction

It has been estimated that approximately 20 percent of the human genome is patented.[1] While this is a generalized statement, most would find this notion, at least in part, unsettling. On the black and white ends of the spectrum, there are those who deeply resent "Microbesofts" and others who see these patents as the key to innovation. As synthetic biology is a relatively new field with unprecedented possibilities, indubitably, there is a great debate surrounding gene patenting in moral, practical, and legal domains.

It is questioned whether the idea of patenting an element of life is immoral: owning or treating genetic material as property is a concern, though some argue this can remedied by having a clearer understanding of what a patent really is. Beyond that philosophical debate is the fear that allowing patents of genetic material could lead to monopolies exhibiting amoral (possibly even unethical) behavior in healthcare and other industries. On the legal end, genetic patents are currently on the hot seat in the courtrooms with some patents being upheld, others not. Many academics feel that the legal patent requirements of "utility," "non-obviousness" and "sufficiently isolated or transformed" are not being appropriately met and that there should be a higher standard for patent acceptance. From a practical perspective, in general, research (the front end) seems to benefit more from open-source systems and idea sharing, while product development (the back end) benefits from patents. The debate consists of where the best balance is to be found.

This paper seeks to elucidate the variety of dilemmas that the synbio-patent interaction has provoked and to hopefully offer some objective commentary and insight for the iGEM and greater synthetic biology community.

2. Moral Issues

Article 53(a) of the European Patent Convention states "inventions, the publication, or exploitation of which would be contrary to 'ordre public' or morality, provided that the exploitation shall not be deemed to be so contrary merely because it is prohibited by law or regulation in some or all of the contracting states" are not accepted.[2] In other words, it contains a clause that says that if a patent is deemed immoral or "contrary to public order" (and not simply because it contains a feature that is literally against the law) it can be denied on those grounds. United States Patent law has no such exact clause but that does not mean that the moral (as distinct from legal) character of a patent is not considered under US law. It is fair to assume that if gene patents were immoral, it would play a role in their legality. Thus, the debate of moral/ethical issues grounded in a philosophical outlook is of relevance. It should be noted that a similar discussion could be had for all organisms, but naturally, preservation of human sanctity is the greatest concern.

THE QUESTION OF GENE PATENTS BEING ANALOGOUS TO "OWNING" SOMETHING HUMAN

For some, the human genome is part of a "common humanity," and thus, the very premise of "patenting" human genetic material seems to violate that humanity[3]. Here, a human gene is a piece of all humans and no one has the right to "own" it; some even make an analogy concerning slavery. Besides this notion that the human genome is a collective property, at the individual level there are claims that gene patents often profiteer off the personal nature of a gene. An example would be a patent on a gene whose cancerous mutation is unique to patient X in some study (which actually was the case in *Moore v. Regents of University of California* for a patent and commercialization of a manipulated cell line originating from John Moore). This version of the gene is part of him/her as an individual. As an analogy, patents on a certain strain or mutation of a gene can be compared to violating the privacy of diaries: they may all read much alike, but their small variations are unique to their author (says Annabelle Lever, Professor of Political Science at MIT) . One has no right to "own" it per se.

However, there is reason to believe that these notions are based on false premises. Pilar Ossorio, Associate Professor of Law and Bioethics at Wisconsin Law School, argues that "patenting" is not "owning." She maintains that "because patents on human genes do not, and legally cannot, apply to genes as they naturally occur in our body…gene patents constitute no threat to the bodily integrity of individuals, or to their use of their own genes in living and reproducing."[4] In other words, the sentiment that a patent can be issued on a gene that is a part of an individual is an unpractical and unrealistic one. For some, it comes down to what legal right the patent actually gives you, and according to Ossorio "the only legal right conferred by a patent is the right to prevent others from using or possessing one's inventions."[4] In the most layman of terms, a patent on something may be had without literally "owning" it, but someone else can't use your idea without your permission.

A counter argument would be that the right to exclude is a very powerful one and behaves a lot like "owning." Annabelle Lever, Professor of Political Science at MIT, argues that the patent's right

to exclude "can basically turn something 'collective' into a private item."[4] What makes something one's property is that one has one's exclusive right to use and possess it. How different is that from not allowing anyone else to use it?

POTENTIAL FOR AMORAL/UNETHICAL ACTION AT THE CONSUMER LEVEL

There is a balance to be struck between rewarding a patentee for his/her efforts and the public's access to the benefits of an invention, especially in the healthcare industry. A landmark case illustrating this dilemma is that of Myriad Genetics, whose patent was recently upheld in an appeals court this past August. Myriad became notorious for its exclusive rights to testing BRCA1 and BRCA2 genes, which assesses a woman's likelihood of developing breast and ovarian cancer. In fact women with mutations in these genes are 7 times more likely to develop breast cancer[3]. The most controversial aspect of this patent is that Myriad's licensing terms are such that all tests are only to be done in and by its own lab and at a price of approximately $3,000.[3]

There are viewpoints that Myriad is exhibiting unethical policies. Sandra Park, an attorney for the ACLU, comments on this monopoly of BRCA testing that "women have only one option for discovering their genetic risk for breast and ovarian cancer."[5] Not only do they not have a chance of a second opinion, but they are also being "led to pay thousands of dollars for treatment," says Nobel Prize Laureate John Sulston.[6] The price is about 3 times more expensive than many genetic tests of a similar scale and though it may be justified somehow, it still seems much. Some economists would argue that, like any other commodity, the laws of supply and demand would dictate the most "fair" price. Many in the healthcare industry believe this to be a faulty assumption. People won't behave so logically when it comes to their health and will be willing to pay significantly more than what a product/service ought to cost (though there is strong disagreement on this notion). Myriad's exclusive patents allow the company to take advantage of this.

In the European Patent Convention, to protect against such dilemmas, therapeutic devices and techniques are not patentable[4]. Though the intent is to promote public health, some disagree with this approach. Biotech patent attorney Tim Worral of Dorsey & Whitney argues that "much of the value in DNA based inventions is on the notion they are patentable."[5] A healthcare product without potential for competition is much more likely to catch an investor's or company's eye and pocket. In his mind, if it weren't for patents, the BRCA testing would not be there in the first place.

SOCIAL/GLOBAL INJUSTICE RISKED BY OVER-PATENTING OF GENES.

The same issues with the Myriad patent could be extended on a societal and global scale. There is potential to further exacerbate gaps between the wealthy and the poor in healthcare and may even prevent poorer countries from being able to benefit from the inventions and discoveries of first world countries. For example, if a patent is made in the United States on a certain mutated crop that can grow in extreme conditions, the inventor could deny or make it very expensive to license development of the strain in the places that need it most (e.g. starving regions of Africa).

Even Ossorio, who earlier argued for the morality of patents concedes that if one interprets people's rights such that "all should have equal access to derived knowledge and beneficial uses of research on the genome" and that "patent holding can prevent the use…of inventions," it would be "unjust to grant patents on the human genome."[4] Granted, researches and investors are entitled to economic reward for their efforts, but there is fear this can be abused.

3. Legality of Gene Patents

DEBATE ON WHAT CONSTITUTES "SUFFICIENTLY ISOLATED OR TRANSFORMED"

While the discussion of the morality of gene patenting has value and can lead to relevant legislation, the current legal debates are more immediately applicable to the direction of gene patenting. The status quo of gene patents in the United States is that genes and other natural biological substances (as well as any associated usage) can be patented if deemed to be "sufficiently isolated or transformed from their naturally occurring state." This is controversial, and relevant patent cases have gone both ways: upheld and overturned.

One of the objections calling for stricter enforcement of these standards argues that genes are information and that even if isolated and manipulated, they are still essentially just information. In 2002, the Nuffield Council on Bioethics, a UK think tank on these issues, maintained that a patent on genes is essentially a patent on information and thus the question of how "isolated" or "manipulated" they are is not too relevant[3]. Co-discoverer of the double helix James Watson has said the following on the on the matter: "[DNA] is a chemical entity, but DNA's importance flows from its ability to encode and transmit the instructions for creating humans. Life's instructions ought not to be controlled by legal monopolies."[5] Watson concedes here that DNA is technically a chemical like many less controversially patentable enzymes and drugs are, but that its value doesn't stem from some unique function but rather from the information it contains. Thus, to patent it would be like patenting a poem (which leads to the question of copywriting as opposed to patenting genes. That issue will be discussed later in this paper).

This is countered by the idea that isolated/manipulated genes are a product of human ingenuity and thus can/should be protected by patents. Along this train of thought, a rock is as un-patentable as a "gene," but a process of decomposing the rock into distinct new compounds and the compounds themselves should be patentable (and they are). Ossorio offers DNA sequencing as an example, arguing that even that process requires much manipulation: isolating DNA from its place in the genome, purifying it, cloning it, denaturing, using some radioactive or fluorescent detection scheme, etc4. In the Myriad Genetics case, before the Federal Circuit appeals decision, the District originally overturned the isolated genes patent. They argued that when they isolate genes from patients, it changes the gene from its original chemical structure and that their corresponding testing was based on this new gene as it existed in its new structure[5]. In the *Parke –Davis and Co. v. H. K. Mulford and Co* case, a human adrenaline patent was upheld because "through purification, it became for every practical purpose a new thing commercially and therapeutically."[7]

In many cases, a synthetic biologist would be unimpressed. These cases often involve procedures that are standard to the entire synthetic biology community, and a gene can be no different practically in or out of the body. Should a PCR and adding bio-brick cut sites really count as isolation/manipulation? There are more complex patents than this, but in the cases where many feel something that should be in the BioBrick registry is being patented instead, it is natural to expect criticism from the academic community with regards to how "isolated" and/or "manipulated" a gene really is.

THE NON-OBVIOUSNESS REQUIREMENT: DISCOVERY, INVENTION, OR CUSTOMARY PART?

A related issue is the question of how "inventive" the claims on a gene patent really are. The subject matter of a patent is required to be non-obvious, a violation consisting of a subject matter that "would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains."[8] There is concern that the threshold for what meets this requirement is too low; for comparison, Europe has 1/7th the amount of patents on DNA sequences that the United States has[9]. Many patented gene sequences are merely acquired by routine techniques (think BioBricking processes), not demonstrating anything truly inventive[3].

This allows opportunity for the genes' nature and other patent content itself to satisfy the non-obviousness requirement. However, what a Federal Appeals Court and the average synthetic biology consider to be obvious may not correspond; a scientist could consider patented parts to be quite customary and expected. An example case is that of gene patent "Molecular Computing Elements, Gates and FlipFlops" (US patent #6,774,222). The claims of the patent involve a molecular data storage mechanism involving DNA, DNA binding proteins, and logic gates.[10] The claims are broad enough so that basic computing functions that are possible by genetic means in general could technically be covered by it. The issue is that when this patent was granted in 2004, many molecular and synthetic biologists knew that "computing functions could be performed using DNA-based "genetic switches."[9] In other words, many found the idea obvious. However, since this knowledge and sentiment was unwritten, a court would be reluctant to use it in determination of "non-obviousness." For contrast, a case in which a similar patent was overturned is *Prometheus v. Mayo*, where a blood test developed by Prometheus Laboratories was decided to simply be a patent of observations on natural phenomena.

Offering another approach calling for stricter standards for non-obviousness, John Sulston's objection to gene patents is that they are often better characterized as "discoveries," not inventions[6]. This thought suggests that a non-obviousness clause could be difficult to apply to synthetic biology as it applied to other fields because the creation of a functional unit (*E. coli* expressing X isolated gene and associated protein, for example) is not analogous to the assembly of nut and bolts. Rather, it is more often an experiment of preexisting biological information (genes) to explore whether a desirable result (functional property in engineered model) can be yielded despite the unpredictable nature of biological systems (at least with our current knowledge set). Thus, many products of synthetic biology could be argued to have more "discovery" character than "invention," though it can be conceded that there are novel man-made sequences.

THE UTILITY REQUIREMENT: THE SPECIFICITY OF THE CLAIMED USE

Fueled by a fear of restricting patents making claims that are too general and unspecified, there is concern that US patent utility requirement will not be sufficiently upheld. A US patent is required to be "useful"; this is in part defined by offering a "specific benefit existing in current available forms."[11] This was the debate revolving around the patenting of ESTs, which received much media attention.

A mild but good example of this issue is the claim of Canadian patent 1,313,830, which is the infamous patent for Monsanto's Round Up Resistant Canola Seed. The "chimeric plant gene" that constitutes

the patent's claims includes a coding sequence for glyphosate-resistant, but more interestingly, "a promoter sequence which functions in plant cells."[12] For a synthetic biologist this is quite general. The plant then indeed lists 3 potential promoters, but that seems to indicate that the patent holder simply wanted to cover every possible promoter they would use, when it is fair for us to assume that the final product would only contain one. A more extreme case would be the patent of "Molecular Computing Elements, Gates and FlipFlops" previously discussed: the patent has 65 claims, many of which are just accounting for what seems to be every reasonable combination of parts they could conceive that could make a system capable of Boolean algebra.[13] There is concern that if patents are irresponsibly accepted on these grounds, when it is unclear how "specific" the claims are and what truly are the "current available forms", it could lead to unnecessarily restricting patents.

4. Practical Issues

BENEFITS OF A PATENT: INNOVATION AND INDIVIDUAL MOTIVATION

Most of the previously described moral and legal objections to gene patent law can be said to be fueled, at least in part, by fear of infringement, restricted research, spending time and money navigating patents, and monopolies in the health care industry. Therefore it becomes important to also discuss and appreciate the argued practical benefits of patenting. In general, private ownership of IP attracts and boosts investment, leading to new products. The ability to patent gives confidence to investors that their dollars will be well spent and will not be subject to competition. Without this, many argue that the fruits of synthetic biology research will be less likely to reach the market and the consumer.

On the individual level, patents offer a very high incentive to potential patent holders. One could restrict competition and give both one's product and oneself credibility. A patent holder can also generate revenue from the licensing or the sale of the patent, royalties being around 5 percent.[14] These benefits motivate product development.

EFFECTS OF LITIGATION FEAR AND THE DANGER OF FOUNDATIONAL PATENTS

However, it can be argued that these said benefits do not outweigh the various cons, one of which can be the effect of fellow researchers fearing litigation. If an investigator faces the possibility that conducting an experiment may infringe on a patent, he/she is less inclined do such research, not to mention the significant time and money lost. The National Academy of Sciences argued that granting EST patents would hinder research in this way.[15] This issue can be amplified by foundational patents (such as EST) being upheld; broad claims equate potential far-reaching research chills.[16] To that effect, literature in the legal domain argues the historical economic evidence that foundational patents slow industry; but those points are highly debated and beyond the scope of this paper.[17] Also, amoral legal behavior could entail a firm buying as many gene patents as possible in a low key fashion, suddenly emerging as the holder when large investments are at stake. This can lead to research and development hold-ups and further increases the likelihood of unintentional infringement.[9] For these reasons there is some demand for a legal clause offering a broad protection of experimental use of patent claims, keeping research unrestricted.[18]

PATENT THICKETS

While foundational patents run a greater risk of inducing fear of litigation, patent thickets are thought to more directly restrict research itself and maybe even product development. Assuming patent standards are low enough, companies and firms can build what are known as "thickets": many patents on a greater number of specific genetic components before any significant experimental research is done. It could be argued that patenting more than is

intended or able to immediately work on makes research on patented items unavailable for the rest of the scientific community.

Thickets may even restrict product development, a counter-intuitive thought (more patents, more investment backed products). Thicket owners could be forced to eventually share licensing and royalties. This cross-licensing is sub-optimal and caps incentives.[19] Monopolies can be formed in each sub-industry (e.g. company X has patents on every promoter causing a hold up, when they all need to negotiate and agree in a crowded patent landscape. In contrast, it has been argued that allowing many patents could prevent monopolies: A spokesman for JCVI on behalf of Craig Venter argued that if "there are a number of companies [with] some degree of patent protection, it would seem unlikely that one group…would be able to hold a 'monopoly' on anything."[6] Regardless, there is a movement promoting the view that if genes are to be patented, it should be done so as specific composite parts. Jay Keasling believes "there is a role to be played by patents, as long as the individual parts themselves remain free."[20] This might strike some sort of ideal balance.

POSSIBLE SOLUTIONS AND THE ROLE TIMING MAY PLAY

With these practical considerations in mind, there are several proposed solutions and/or compromises possible in the controversy around genetic patenting. Some argue that a complete open source system is best; this is the premise behind the BioBricks Registry. The idea is that research is accelerated by the public sharing of ideas and creations, and this appears to be true for BioBricks. The problem is that once a brick is in the Registry, it is "public knowledge" and becomes invalid for patenting. This is believed by some to hinder an investor's incentive to help develop research into the product. There is interest in maximizing the possibility of product development that could benefit mankind. With this in mind, a complete open source system with no room for intellectual property (which "biopunks" and the DIYbio group advocate for) could seem flawed and thus more balanced solutions should be considered.[18]

A very notable compromise is the concept of copyleft. A copyleft is basically a copyright that allows free licensing to use and distribute the copyleft material, with a requirement that all downstream modifications or new copyrighted material involving the original copyright also must benefit from free licensing. In other words, the inventor/write can get credit and legal benefits without restricting any use. Also, copyrights/lefts are in general less expensive than patents.[16]

What is in part preventing the use of this option in synthetic biology is that copyrights cover "original works of expression...excluding works that are functional." In contrast, patent law "requires functionality." An example: DNA sequences that use non-standard base pairs (ATCG) allow room for expression and novelty; however, most synthetic biologists are "working in the confines of existing genetic code."[16] With this in mind, there is no strong basis for a court to grant genetic patents a copyright/copyleft license. Patents do have a "patentleft" option as well, allowing the idea of copyleft to be applied to the field of synthetic biology. However, patents are in general more expensive than copyrights.[16]

It should be noted that copylefts and patentlefts can still lower incentives for IP investment. If everything downstream of patentleft (any new item containing any part of the original patent) is required to have free licensing, investors have to fear competition and might be less inclined to invest.

However, other positives could also be fairer pricing and ultimately more available choice in industries that synthetic biology contributes to.

Another balanced possibility is that of a non-assertion model for patents, which basically acts as a copyleft condition but only for research. This basically means the patent owner vows to not assert its patents against those who wish to use its claims for academic and research purposes, but requires a license for those who wish to have a property right or create a product.[16] This would enable synthetic biology to grow without hindering IP investment interest. This is of course a more nuanced patent agreement: nuance requires better lawyers, and better lawyers often equate a greater financial expense for an individual synthetic biologist.

There is reason to believe that timing could play a role into what model—whether it be open source, patent, patentleft, or non-assertion—at a given point in the growth of the synthetic biology industry is ideal. Randy Rettberg, director of the MIT BioBrick Registry argues that "software started out free of copyright and patents for many years. As synthetic biology begins, there will be lots of new ideas [and] if patents are enforced, the field will be blocked."[20] As synthetic biology has been developing for about two decades now, if one considers the field young - and many do, considering its potential and possibilities, - the industry and research might benefit from being an open source until it reaches full maturity. At that point in time, patent-based systems may be more appropriate: less controversial and less restrictive..

UNPREDICTABLE FUTURE AND FINAL THOUGHTS

My favorite legal case in synthetic biology is *Monsanto Canada Inc. v. Schmeiser*. Schmeiser, a canola farmer, claims to have found a small area of his crops that were unexpectedly resistant to and survived *RoundUp* (a herbicide). He then decided to plant his entire canola crop, with seeds from the especially healthy strain, towards the next harvest. It was later found that his canola crops contained the Monsanto patented glyphosate-resistant cells (and consequently, glyphosate-resistant gene construct) whose market name was "Roundup Ready Canola." Schmeiser was sued for patent infringement, Schmeiser arguing that he had a right to use what was his property and that the presence of RoundUp Ready in his crops was out of his control and accidental (perhaps it came from a nearby canola crop).

The canola farmer ultimately lost the case. Many of the previously discussed issues in synthetic biology and patenting are relevant there, but another thought came to mind. Assuming the presence of this strain in his crop was truthfully accidental, what does that suggest about the sort of issues that society may face when the world around us becomes filled with the patented products of synthetic biology? What sort of effect would patents have in a world full of often self-replicating patent claims (e.g. genetically engineered cells like the RoundUp Ready Canola)? Will individuals get sued when their neighbor's bioproducts accidently creep their way into their homes?

Let's also for a moment consider that a patent currently lasts only 20 years, or as Jimmy Huang of the 2008 UCSF iGEM noted, there may be cases where a university has contractual ownership of products its faculty invented.[21] In other words, predicting the effects the field of synthetic biology and gene patenting will have in the long run is a slippery slope. No solution

or thought offered in this paper is perfect and each one represents different ideologies and practical values; consensus in such a debate is difficult. Nonetheless, the community can be open-minded, informed, and thinking deeply about these issues. Hopefully this paper will advance that goal. In the end, that's the only way this field will progress optimally and ethically.

Works Cited

1. Mick, Jason. "Twenty Percent of Human Genome Is Patented, ACLU Battle to Determine Legality." Daily Tech. N.p., 22 Jan. 2010. Web. <http://www.dailytech.com/Twenty+Percent+of+Human+Genome+is+Patented+ACLU+Battle+to+Determine+Legality/article17489.htm>.

2. Thambisetty, Sivaramjani. "Understanding Morality as a Ground for Exclusion From Patentability Under European Law." Eubios Journal of Asian and International Bioethics 12 (2002): 48-53. Eubios. Web. <http://www.eubios.info/EJ122/ej122b.htm>.

3. "Ethics and Gene Patents." Human Genetics Commission.Web. <http://www.hgc.gov.uk/Client/Content_wide.asp?ContentId=372>.

4. Lever, Annabelle. "Ethics and the Patenting of Human Genes." The Journal of Philosophy, Science & Law 1 (2001): Manuscripts and Articles. Web. <http://www6.miami.edu/ethics/jpsl/archives/papers/ethics_lever.html>.

5. Stempel, Jonathan. "Myriad Wins Gene Patent Ruling from US Appeals Court."Reuters. Thomson Reuters, 16 Aug. 2012. Web. 1 Sept. 2012. <http://www.reuters.com/article/2012/08/16/us-myriad-patent- idUSBRE87F12K20120816>.

6. Cairns, David. "Don't Let Venter Patent Artificial Life, Says Rival" The Week. Dennis Publishing, 25 May 2010. Web. <http://www.theweek.co.uk/politics/14403/don%E2%80%99t-let-venter-patent- artificial-life-says-rival>.

7. Parke-Davis and Co. v. H.K. Mulford and Co., 189 F. 95, 102 (SDNY 1911), affd. 196 F. 496 (Second Cir. 1912). Quoted In Ossorio, p. 8

8. "35 U.S.C. 103 Conditions for Patentability; Non-obvious Subject Matter." United States Patent and Trademark Office. N.p., 18 Dec. 2008. Web. 2 Sept. 2012. <http://www.uspto.gov/web/offices/pac/mpep/documents/appxl_35_U_S_C_103.htm>.

9. Kumar, Sapna, and Arti Rai. "Synthetic Biology: The Intellectual Property Puzzle."Texas Law Review 85 (2007): 1745-768. Print.

10. Rai, Arti, and James Boyle. "Synthetic Biology: Caught between Property Rights, the Public Domain, and the Commons." PLoS Biol. E58 5.3 (2007): n. pag. PMC. NCBI, 13 Mar. 2007. Web. 1 Sept. 2012. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1821064/>.

11. Jackson, Chris. "An IGEM-Specific Guide to U.S. Intellectual Property and Patent Law."Http://2012.igem.org/Team:Stanford-Brown.

12. Shah, Dilip M., Stephen G. Rogers, Robert B. Horsch, and Robert T. Fraley. Glyphosate-Resistant Plants. Canadian Intellectual Property Office. Patent 1313830. 23 Feb. 1993.

13. Schneider, Thomas. Molecular Computing Elements, Gates and Flip-flops. The United States of America as Represented by the Department of Health and Human Services, assignee. Patent 6774222. 10 Aug. 2004.

14. “Patent Pros & Cons.” Inventor Basics. Inventorbasics.com, 2011. Web. <http://www.inventorbasics.com/Patent%20Pros%20&%20Cons.htm>.

15. Kintisch, Eli. “Appeals Court Bars EST Patent.” Science NOW. Science, 8 Sept. 2005. Web. 2 Sept. 2012. <http://news.sciencemag.org/sciencenow/2005/09/08-02.html>.

16. Rai, Arti, and James Boyle. “Synthetic Biology: Caught between Property Rights, the Public Domain, and the Commons.” PLoS Biol. E58 5.3 (2007): n. pag. PMC. NCBI, 13 Mar. 2007. Web. 1 Sept. 2012. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1821064/>.

17. Merges RP, Nelson RR. On the complex economics of patent scope. Columbia Law Rev.1990;90:839–916.

18. McLennan, Alison, and Matthew Rimmer. “Inventing Life: Patent Law and Synthetic biology.” The Conversation. N.p., 27 Feb. 2012. Web. 3 Sept. 2012. <http://theconversation.edu.au/inventing-life-patent-law-and-synthetic-biology-5178>.

19. Bessen, James. “Patent Thickets: Strategic Patenting of Complex Technologies.” Boston University School of Law, Web. 1 Sept. 2012. <http://papers.ssrn.com/sol3/papers.cfm?abstract_id=327760>.

20. “Sparks of Creation.” Chemistry World. RSC, n.d. Web. 11 Sept. 2012. <http://www.rsc.org/chemistryworld/Issues/2008/July/SparksOfCreation.asp>.

21. Huang, Jimmy. “Patents and IGEM.” UCSF IGEM. N.p., 2008. Web. 1 Sept. 2012. <http://2008.igem.org/Team:UCSF/Human_Practices>.