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THE PENGUIN'S GENOME, OR COASE AND OPEN SOURCE BIOTECHNOLOGY

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I. INTRODUCTION

In computers, code is precise; code is predictable; code is persistent; perhaps code is even law. Indeed, computer code's relative precision, predictability, and persistence — the fact that a given set of instructions will reliably produce a given output — is what allows code to function as law. Furthermore, these features allow code to evolve in varied environments, including open source environments. Open source production, in which individuals may modify and develop the "law" of code, has been hailed as an egalitarian economic system as well as an efficient means of production. This Article assesses the feasibility of applying open source principles to the biotechnology industry.

The open source software movement has gained widespread acceptance as a viable distribution model. The Linux operating system and Apache web server, for example, are widely used open source software products with extensive development communities. The success of this movement has generated substantial excitement about whether open source development principles can be applied to other technologies. Many online publications, ranging from the Wikipedia[1]

1. Wikipedia is a free online encyclopedia whose content is produced by independent individuals who submit their work for publication. *See* Wikipedia: The Free Encyclopedia, *at* http://www.wikipedia.org (last visited Nov. 29, 2004) [hereinafter Wikipedia].

encyclopedia to individual weblogs,[2] have begun to draw on open source principles by making their content freely modifiable and distributable.

There are some established criteria for determining, as a practical matter, whether open source production methods can extend to a new technology. The first step in this process is to divide the technology into "layers."[3] The Internet, for example, contains "hardware" layers (the machinery that runs the network), "software" or "code" layers (the protocols that allow information to travel over the network), and "content" layers (the information being communicated).[4] Once the different layers have been identified, the next analytical move is to determine whether open source production would be feasible and efficient with respect to any given layer. In his article *Coase's Penguin, or, Linux and the Nature of the Firm*, Yochai Benkler established that modularity, a project's divisibility into asynchronous modules, and granularity, the nature of those modules as manageably small components, are key factors in this determination of feasibility and efficiency.[5] As Lawrence Lessig has argued, under Benkler's criteria, the best candidate for open source development usually is a "code" layer, because code typically is modular and granular.[6] Moreover, code controls who has access to the network and what information flows over it — in other words, "code is law."[7] Insofar as anyone can contribute to and modify the coded law, open source code is an egalitarian exercise, as well as an efficient means of production.[8]

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2. A weblog is a "web application which contains periodic, reverse chronologically ordered posts on a common webpage." *See* Wikipedia, Weblog, *at* http://en.wikipedia.org/wiki/Weblog (last modified Sept. 30, 2004).

3. *See* Yochai Benkler, *From Consumers to Users: Shifting Deeper Structures of Regulation*, 52 FED. COMM. L.J. 561, 562–63 (2000); *see also* LAWRENCE LESSIG, THE FUTURE OF IDEAS 23–25 (2001).

4. LESSIG, *supra* note 3, at 23–25.

5. Yochai Benkler, *Coase's Penguin, or, Linux and the Nature of the Firm*, 112 YALE L.J. 369 (2002). See *infra* text accompanying notes 69–74. This section includes definitions and further discussion of modularity and granularity as attributes of divisibility. Divisibility classically has strong implications for efficiency and feasibility of production, for example, in gains from the division of labor.

6. LESSIG, *supra* note 3, at 23–25.

7. LAWRENCE LESSIG, CODE AND OTHER LAWS OF CYBERSPACE 4–8 (1999). As Lessig notes, applying his understanding of "code" to the Internet:

> If the code of cyberspace is owned . . . it can be controlled; if it is not owned, control is much more difficult. The lack of ownership, the absence of property, the inability to direct how ideas will be used — in a word, the presence of a commons — is key to limiting, or checking, certain forms of governmental control.

Id. at 7.

8. *See* LESSIG, *supra* note 3, at 246–47; *see also* Anupam Chander & Madhavi Sunder, *The Romance of the Public Domain*, 92 CAL. L. REV. 1331, 1360 (2004) ("A glance at Linux's rapid adoption worldwide demonstrates that Linux has an egalitarian streak.").

In many ways, the analysis is similar when the technology is biologically based. It is possible to identify distinct layers in an organic communications system: "hardware" layers of cells, tissue, or organism; "software" layers of genetic code; and "content" layers of proteins and chemical cascades, produced according to the code's instructions, that affect the organism and its environment. In some respects, genetic code functions as "law" to an organism. And, increasingly, genetic code can be manipulated to change the rules. Indeed, Lessig analogizes his view of how "code" functions on the Internet to the manner in which DNA functions in a living organism.[9] Given these perceived similarities between computer code and biological code, the open source software movement's success in creating stable, useful products and its egalitarian spirit have fueled interest in whether open source production models can be applied to biotechnology.

Recent intellectual property law developments have added fuel to the fire. The law seems to be moving in the direction of privatization and away from a traditional "commons." For example, courts have held that genetically engineered living organisms are patentable[10] and that basic university research is not beyond the reach of patent infringement claims;[11] the Bayh-Dole Act opened government-funded research to private patent claims;[12] the U.S. Patent Office issued guidelines that allow patents on genetic sequences with a known utility;[13] Congress passed the Digital Millennium Copyright Act, which effectively gives encryption technology, including that used to encrypt bioinformatic databases, the force of law;[14] and the European Union adopted a Database Directive, which might find its way in some form into U.S. law, that provides sui generis protection for databases.[15] Some scholars and commentators argue that these developments have created an "enclosure," "patent thicket," or "anticommons" in the biotechnology arena.[16] There have been heated calls for a "reconstruction" of the biotechnology commons, a debate in which open source models take prominence.[17]

However, there are problems with an open source approach, arising both from the nature of biological code and the nature of the re-

9. *See* LESSIG, *supra* note 7, at 101–02 ("[The Internet] is perhaps not quite as amazing as nature — think of DNA — but it is built on the same principle: keep the elements simple, and the compounds will astound.").

10. *See* Diamond v. Chakrabarty, 447 U.S. 303, 303 (1980).

11. *See* Integra Lifesciences I, Ltd. v. Merck KGaA, 331 F.3d 860, 861 (Fed. Cir. 2003).

12. 35 U.S.C. §§ 200–12 (2000).

13. Utility Examination Guidelines, 66 Fed. Reg. 1092–02 (Jan. 5, 2001).

14. 17 U.S.C. §§ 1201–05 (2000).

15. Legal Protection of Databases, Council Directive 96/9, 1996 O.J. (L77) 2.

16. *See* discussion *infra* Part IV.

17. *See* discussion *infra* Part IV.D.

search community that codes biotechnology. In biological organisms, code is not as precise, predictable, or persistent as computer code. The basis for organic code — DNA — can be mapped, but it often is difficult to connect bits of DNA with specific biological outcomes. Also, because organic code is part of a functioning organism, it causes changes in the organism, the organism's environment, and other organisms. In turn, it is changed by its surroundings. The dynamic nature of organic code and the fragility of the systems within which it finds expression raise unique challenges for defining which, if any, aspects of organic code are "law" and which, if any, aspects of organic code can be evolved through open, collaborative development models.

In addition, open source development will work only within an existing community with a prestige-based reward structure mediated by authoritative voices who can define what constitutes an authentic version of the open-sourced product. Although previous discussions of open source biotechnology have assumed that such a community exists, that assumption has been based largely on outdated and overly romantic notions of the "community of science." In reality, biotechnology research is a competitive enterprise in which norms of openness and sharing are limited and complex, raising serious questions about whether existing norms could support extensive open source development.[18]

Even if open source models could work in biotechnology as a practical matter, one must ask the normative question whether law and public policy *should* support such models over alternatives based on government control or privatization. Previous normative discussions of open source approaches to biotechnology have focused on an idealized "information commons" that does not map neatly onto the world of biological code. Moreover, the discussion has not examined how the differences between computer code and biological code relate to the traditional understanding of a commons, or how such differences might impact open source development models.

In the idealized information commons, information is considered a non-rival resource, and therefore it exists without the threat of the "tragedy" of its eventual depletion by rationally self-interested users.[19] Since limitations on access are not needed to protect the resource, property restrictions that potentially reduce efficiency gains from sharing would need to rest on a strong incentive-based justification. If

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18. The Fall 2004 launch of the Biological Innovation for Open Society ("BIOS") initiative, an open source movement for the development of biotechnology products, will be an interesting test of the viability of the open source model for the industry. *See* Carina Dennis, *Biologists Launch 'Open-Source Movement*,*'* 431 NATURE 494 (2004), *available at* http://www.bios.net/uploads/66/ z9rkT0KOA8A_fduD2q0M9A/ Nature_News_Piece.pdf.

19. *See infra* Part IV.B.

the incentive to produce consists primarily of psychological or social rewards, for example, the incentives provided by intellectual property protection might not be needed. Under such circumstances, development might more efficiently occur in an open source environment where multiple minds could simultaneously be working off the common base of resources. The result is not only a more efficient production process, but also a more open information commons.

In this respect, information-commons theory reflects earlier views about the public domain. The framers of the U.S. Constitution and its Copyright Clause came from an Enlightenment model that viewed the progress of science as a continual unveiling of a fixed Natural Law, which constituted the public domain.[20] Information-commons theory draws from the same vein when it supposes that information is non-rival, and that it is a binary quantity that is either "open" or "closed."

When applied to biotechnology, this view of information is outdated. If information is a disembodied set of facts or ideas, it is correct to say that information is non-rival. However, if information is properly viewed as something embedded in a particular economic, social, and biological context, non-rivalry becomes chimerical. The organic nature of biotechnology, as well as the dynamic, venture-funded manner in which biotechnology research and development occurs, suggest that the ideal of non-rivalry is not a useful model for the biotechnology commons.

If an open source, non-rival commons-based model seems practically and normatively ill-suited to biotechnology, is the situation hopeless? This Article argues that it is not. As with any commons problem involving a rivalrous resource, tragedy can be averted through government control, voluntary collective action, or privatization with Coasian bargaining. This Article argues that continued privatization could be a useful way of managing the biotechnology commons if transaction costs for negotiating access can be reduced. To that end, this Article outlines a central "market" where clear data about proprietary rights claims, license terms, and prices would be available to all. Although this solution is not perfect, it seems better than deprivatizing intellectual property assets to force the creation of a government or collectively-run commons.

My analysis proceeds as follows. Part II of this Article describes the current landscape of the biotechnology commons, including a discussion of the proprietary rights that have alarmed many commentators. Part III discusses whether open source principles can be applied to biotechnology as a practical matter. This Article treats a typical biotechnology patent as an example of the different layers in biotech-

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20. *See infra* Part IV.A.

nology and discusses whether those layers could fit into an open source paradigm. Part IV examines whether open source should be applied to biotechnology as a normative matter. In particular, this Article reviews prevailing conceptions of the public domain and the information commons, then identifies why these conceptions do not map well onto biotechnology. Finally, Part V discusses typical objections to a Coasian approach for the biotechnology commons, and outlines my proposal for a central market to reduce transaction costs associated with private bargaining over biotechnology rights.

II. BIOTECHNOLOGY AND PROPRIETARY RIGHTS

A. Mining Diamond

Before delving into specifics of the biotechnology commons debate, it is useful to construct a map of the biotechnology commons and examine why recent changes in intellectual property law have caused alarm. The law has developed in recent years to provide a broad array of intellectual property and other proprietary protections for biotechnology. The revolution began with the U.S. Supreme Court's decision in *Diamond v. Chakrabarty*,[21] in which the Court held that genetically engineered living organisms are patentable subject matter.

The dispute in *Diamond* revolved around a bacterium that had been genetically engineered to digest oil waste. The inventor submitted a patent application with three types of claims: one for a method of producing the bacterium, another for a method of using the bacterium in a solution, and a third for the organism itself.[22] The organism claim was rejected by the patent examiner and the Patent Office Board of Appeals based on a general policy against patenting living things as found in the legislative history of the Plant Patent Act.[23]

Finding the holding of *Parker v. Flook*[24] inapplicable in this case, the Supreme Court read the Patent Act broadly to permit the patenting of "anything under the Sun that is made by man."[25] Further, the Court rejected a *per se* rule against patenting living organisms. In this bold stroke, the Court opened the biotechnology commons to private stakeholders.

21. 447 U.S. 303 (1980).
22. *See id*. at 305–06.
23. 35 U.S.C. §§ 161–164 (2000).
24. 437 U.S. 584 (1978) (holding that "the laws of nature, physical phenomena, and abstract ideas" are not patentable).
25. *Diamond*, 447 U.S. at 309 (citing Committee Report on 1952 Patent Act, S. REP. NO. 82–1979, at 5 (2d Sess. 1952)).

B. The Bayh-Dole Act

Also in 1980, Congress passed the Bayh-Dole Act.[26] Bayh-Dole modified long-standing policies limiting patenting of inventions developed with government funding. Under Bayh-Dole, a university or small business can elect to seek patent protection for inventions developed with government funding.[27] As a result, university patent holdings have skyrocketed, and the academic technology transfer industry was born.[28]

C. Gene Patents

After *Diamond*, the Patent Office wrestled with guidelines for patenting biologically derived inventions, including genetic sequences. In 2001, the Patent Office adopted guidelines that permit the patenting of genetic sequence data if the sequence is tied to a known utility. Thus, patents can be obtained on gene sequences that code for particular proteins with known uses.[29] Now, not only entire organisms — hardware, code, and content (in open source lingo) — but code alone (so long as the code produces known, useful content) is subject to private rights.

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26. 35 U.S.C. §§ 200–212 (2000).

27. *See id*. § 200. The statute states:

> It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development; to encourage maximum participation of small business firms in federally supported research and development efforts; to promote collaboration between commercial concerns and nonprofit organizations, including universities; to ensure that inventions made by nonprofit organizations and small business firms are used in a manner to promote free competition and enterprise without unduly encumbering future research and discovery; to promote the commercialization and public availability of inventions made in the United States by United States industry and labor . . . .

Id.

28. *See* COUNCIL ON GOVERNMENT RELATIONS, THE BAYH-DOLE ACT: A GUIDE TO THE LAW AND IMPLEMENTING REGULATIONS (Oct. 1999), *at* http://www.ucop.edu/ott/bayh.html (noting that academic institutions obtained over 8,000 patents between 1993 and 1997 and that over 2,000 companies have been formed since 1980 based on patent licenses from academic institutions).

29. *See* Utility Examination Guidelines, 66 Fed. Reg. 1092-02 (Jan. 5, 2001). The guidelines have been hailed by biotechnology industry leaders as "the Magna Carta of biotechnology." David Holzman, *Gene Patent Guidelines "Magna Carta" of Biotechnology*, GENETIC ENG'G NEWS (Feb. 1, 2001), *available at* http://www.mindfully.org/GE/Biotech-Magna-Carta.htm.

D. Research Tools and Experimental Use

The Federal Circuit recently narrowed the experimental use defense long used by research universities against patent infringement claims. In *Madey v. Duke University*,[30] the Federal Circuit considered for the first time whether a nonprofit research university accused of patent infringement should be treated differently than a commercial institution. The dispute in *Duke* arose when Madey sued his former employer, Duke University, for infringing his patents on free electron laser ("FEL") laboratory equipment. Madey had obtained sole ownership of two patents covering some of the equipment while at Stanford. Duke recruited Madey, where he served as the director in the FEL lab for nearly ten years. Following a dispute with the university, Madey resigned from Duke, but the university continued to operate the patented equipment without his permission. Madey sued Duke for infringement of his two patents. The district court held that the alleged infringing acts were excused under the experimental use defense.[31]

The Federal Circuit reversed the district court's decision and found that the experimental use defense is "very narrow and strictly limited."[32] The experimental use defense would only apply if the user experimented "for amusement, to satisfy idle curiosity, or for strictly philosophical inquiry," not for commercial purposes.[33] Adopting a broad definition of commercial purpose, the court found that Duke's projects fell outside the experimental use defense because they furthered the university's overall business goals of teaching students and producing scholarship.[34] The Federal Circuit thus effectively disqualified all research universities from using the experimental use defense.

E. Preclinical Research and Safe Harbors

Another barrier to the research commons was erected by the Federal Circuit in *Integra Lifesciences I, Ltd. v. Merck*,[35] which concerned the "safe harbor" provision of the Bayh-Dole Act.[36] The safe harbor provision permits the use of patented inventions that are primarily manufactured using recombinant DNA, recombinant RNA, hybridoma technology, or other similar genetic technologies when

30. 307 F.3d 1351 (Fed. Cir. 2002).
31. *See id*. at 1355.
32. *Id*. at 1362.
33. *Id*.
34. *See id*. at 1362–63.
35. 331 F.3d 860 (Fed. Cir. 2003).
36. 35 U.S.C. § 271(e)(1) (2000).

employed solely to develop and submit information required by federal law.[37]

Integra owned patents relating to a peptide sequence that promotes the adhesion of cells to substrates.[38] Making use of materials covered by Integra's patents, Merck conducted research concerning the ability of certain peptides to inhibit angiogenesis[39] to identify potential anti-angiogenic candidates for human testing.[40] Integra sued, claiming that Merck's pre-clinical trial research activities constituted patent infringement.[41] Merck claimed safe harbor protection because its end goal was to submit its product to the Food and Drug Administration ("FDA") for approval, for which it would need to generate data required by federal law.[42]

The Federal Circuit rejected Merck's safe harbor defense on the narrow ground that Merck's research was in the pre-clinical trial phase, and thus did not directly generate data required by the FDA.[43] In particular, the court was concerned that a more expansive reading of the safe harbor provision "would effectively vitiate the exclusive rights of patentees owning biotechnology tool patents."[44] *Integra* is a ringing endorsement of patent rights in research tools.

F. DRM and Bioinformatics

At first blush, the Digital Millennium Copyright Act ("DMCA")[45] might seem unrelated to biotechnology. The biotechnology revolution, however, is being made possible by the application of advanced computer technology to biological data, a discipline called bioinformatics.[46] Although a collection of such data could possibly be protected by copyright as a collective work, it is doubtful that simple aggregation of basic factual data would qualify for copyright protection after the Supreme Court's *Feist* decision.[47] However, even non-

37. *See id*.

38. *See Integra*, 331 F.3d at 862–63.

39. Angiogenesis is the process by which blood vessels are formed from preexisting vessels, and is a factor in the transition of tumors from benign to malignant. *See* Wikipedia, Angiogenesis, *at* http://www.wikipedia.org/wiki/Angiogenesis (last modified July 28, 2004).

40. *Integra*, 331 F.3d at 863.

41. *See id*.

42. *See id*.

43. *See id*. at 866 ("The FDA has no interest in the hunt for drugs that may or may not later undergo clinical testing for FDA approval.").

44. *Id*. at 867.

45. 17 U.S.C. § 1201 (2000).

46. *See* Wikipedia, Bioinformatics, *at* http://en.wikipedia.org/wiki/Bioinformatics (last modified Sept. 24, 2004).

47. Feist Publ'ns Inc. v. Rural Tel. Serv., 499 U.S. 340 (1991) (holding that a telephone directory lacked the basic degree of creativity needed for copyright protection).

copyrightable data can be locked up through digital rights management ("DRM") technology. The DMCA prohibits the circumvention of such technology,[48] essentially allowing the author of a biological database to self-determine her level of proprietary rights.

G. Database Protections

In addition to the DMCA's anti-circumvention provisions, there has been an increasing movement in the United States towards a sui generis right in databases.[49] In this respect, the United States is behind Europe, which already has adopted a sweeping database directive that protects the sweat of the brow in databases.[50] In Europe, bioinformatic databases cannot be freely used or copied, and the United States may soon follow.

H. An Example

It is useful to illustrate how this soup of intellectual property rights relates to a typical biotechnology invention. This example comes from the field of industrial biotechnology, a branch of biotechnology that seeks to use biological processes to create useful products.[51] The World Congress on Industrial Biotechnology and Bioprocessing recently convened for the first time as a major gathering of leaders in this industry.[52] Although the industry is young, it holds great promise. As the Biotechnology Industry Organization's ("BIO") president, Carl Feldbaum, breathlessly told those assembled at the Congress, "We are dealing with nothing less than the future of life itself. Industrial biotechnology can lead the way to environmentally sustainable industrial and economic growth."[53]

Although BIO's rhetoric is hyperbolic, it is not all hype. Iogen, a Canadian company, recently announced that it has engineered bacteria that produces enzymes capable of converting wood-product manufacturing residues and agricultural waste such as corn husks (called bio-

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48. 17 U.S.C. § 1201.

49. *See* Jerome Reichman, *Discussion Framework*, *in* NAT'L RES. COUNCIL, THE ROLE OF SCIENTIFIC AND TECHNICAL DATA AND INFORMATION IN THE PUBLIC DOMAIN 73, 82–85 (2003), *available at* http://www.nap.edu/books/030908850X/html/ (discussing proposals for database protection in the United States).

50. *See* Legal Protection of Databases, Council Directive 96/9, 1996 O.J. (L77) 2. For a discussion of the European Database Directive, see Reichman, *supra* note 49, at 81–82.

51. *See Sea of Dreams*, THE ECONOMIST, May 1, 2004, at 81.

52. *See* World Congress on Industrial Biotechnology and Bioprocessing, Industrial Biotech Takes Center Stage at the World Congress in 2004, *at* www.bio.org/worldcongress/media/20040426.asp (last visited Nov. 29, 2004).

53. *See id*.

mass) into ethanol, a clean burning fuel.[54] Obviously, the availability of such a process could be ecologically and economically revolutionary. In fact, cheap, clean fuel, produced via a process that includes the spillover benefit of reducing agricultural biomass, is just the sort of technology that might implicate the most idealistic hopes of an information commons.

Iogen has patents in the key technologies relating to its bioethanol product.[55] These include a patent on the genetically engineered microbes used in the process.[56] A review of Iogen's microbe patent reveals the sorts of rights that must be cleared to engineer the microbe. The Iogen example is useful in illustrating the impact of proprietary rights on the development of biotechnology as a whole, because the techniques used by Iogen are, for the most part, typical in genetic engineering.

The examples provided in the '703 Patent Specification describe the following steps in engineering the ethanol-producing microbe: (1) the appropriate microbial host is selected; (2) the host's genomic DNA is isolated; (3) genomic libraries are constructed from the host's genomic DNA; (4) probes are designed to isolate from the genomic libraries the gene that codes for the target enzyme; (5) the target gene is isolated; (6) vectors are created for introducing the target gene into colonies of the microbial host; and (7) strains of clones from these colonies that are expressing the target enzyme in increased quantities are cultured.[57]

These basic steps reflect standard cloning technique. There are numerous patents on technologies that relate to these steps. Figure 1, for example, identifies some patents that might apply at each step.

In addition, the '703 Patent identifies various pieces of commercially available equipment and chemicals used in the cloning process.[58] Much of this equipment is subject to patent and other intellectual property rights. Finally, the '703 Patent identifies some published data relating to the genomic libraries and the cloning methods used.[59] At least some of this published data presumably is covered by copyright, and some potentially could be protected by anti-circumvention or database protections if it is in electronic form.

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54. *See* Press Release, BIO, Biotech Breaks Through the Cellulose Barrier with First Commercial Shipment of Bioethanol (Apr. 22, 2004), *at* http://www.bio.org/news/newsitem.asp?id=2004_0422_01.

55. *See* U.S. Patent No. 6,090,595 (issued Jul. 18, 2000); U.S. Patent No. 6,015,703 (issued Jan. 18, 2000); U.S. Patent No. 5,916,780 (issued Jun. 29, 1999).

56. U.S. Patent No. 6,015,703 (issued Jan. 18, 2000) [hereinafter '703 Patent].

57. *See id.*

58. *See id.*

59. *See id.*

Figure 1: Applicable Patents During Various Stages of Cloning

Stage of Cloning	Applicable Patent
Construction of T.reesei genomic libraries	
↓	
Lamda DASH vector	5,188,957 Lamda packaging extract lacking β-galactosidase activity
↓	
Digest DNA	5,137,823 Method for producing the BamHI restriction endonuclease 5,192,675 Cloned KpnI restriction-modification system
↓	
Electro-elute fragments	5,415,758 Method and apparatus for electro-elution of biological molecules
↓	
Ligate fragments into vector	
↓	
Electroporate ligation reactions	6,586,249 Method for more efficient electroporation
↓	
Identify transformant libraries	4,533,628 Colony hybridization method
↓	
Prepare probes to identify clones	4,683,195 Process for amplifying, detecting, and/or cloning nucleic acids 4,683,202 Process for amplifying nucleic acid sequences

It is clear, then, that an innovator does face a bevy of proprietary rights hurdles that must be cleared to access the biotechnology commons. The question is whether those hurdles represent unnecessary barriers to the commons, and, if so, whether those barriers can or should be removed through open source development principles. To answer this question, this Article first examines whether open source principles can apply to biotechnology development as a practical matter. Following that analysis, this Article discusses whether open source principles should apply to biotechnology development as a normative matter.

III. THE PENGUIN'S DNA

To address the threshold question of whether open source principles can apply to biotechnology as a practical matter, this Article first defines "open source" through a review of the open source software movement. Then, it identifies the key criteria for whether open source development can occur and applies those criteria to the mechanics and culture of biotechnology development.

A. The Open Source Software Movement

The open source software movement has achieved almost mythic status in some circles. Made possible by an equally revolutionary tool, the Internet, it has been hailed as a revolutionary means of organizing production and society on more egalitarian lines.[60] And, because open source methods potentially are infinitely scalable for the production of various resources, these methods have been the prime focus of many theorists' attention as a means of maintaining an open commons.[61]

Exactly what "open source" means is a subject of some confusion and debate. To some extent, the confusion stems from the mistaken equation of "open" with "free." For example, the author of open source software might charge for it.[62] Nor does open source necessarily entail complete dedication to the public domain. In fact, much open source software is distributed under a copyright license.[63] Open source does mean, however, that the software is distributed with its source code as well as a license that allows for the free creation and distribution of derivative works.

The Open Source Initiative's ("OSI") definition of open source explains why the components of access to source code, free derivative work, and redistribution are critical for the open source license.[64] With regard to source code, the OSI notes that "you can't evolve programs without modifying them. Since our purpose is to make evolution easy, we require that modification be made easy."[65] In terms of derivative works, the OSI states that "[t]he mere ability to read source isn't enough to support independent peer review and rapid evolutionary selection. For rapid evolution to happen, people need to be able to experiment with and redistribute modifications."[66] Finally, with free

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60. *See, e.g.*, LESSIG, *supra* note 7, at 4–8.

61. *See, e.g.*, *id*.

62. *See* Wikipedia, Open Source, *at* http://en.wikipedia.org/wiki/Open_source (last modified Oct. 7, 2004).

63. For a discussion of open source licensing principles, see *infra* Part III.B.6.

64. Open Source Initiative, The Open Source Definition (2004), *at* http://www.opensource.org/docs/definition.php. The Open Source Definition was crafted by early proponents of the open source movement, including Eric Raymond, John "Maddog" Hall, and Bruce Perens, in response to what they viewed as the overly confrontational stance of the free software movement. *See* Wikipedia, Open Source Movement, *at* http://en.wikipedia. org/wiki/Open_source_movement (last modified Sept. 24, 2004).

65. Open Source Initiative, *supra* note 64.

66. *Id*.

redistribution, the OSI concludes that "[i]f we didn't do this, there would be lots of pressure for cooperators to defect."[67] Under the OSI's formulation, open source licensing creates a contractual public domain in as much of the author's bundle of rights as is necessary to permit technological evolution.[68]

B. Biotechnology and the Criteria for Open Source Production

1. When is the Open Source Model Viable?

The open source ideal is easy to state, but harder to implement. In particular, it can be difficult to determine how, if at all, the open source principles developed in the software hacker culture can transfer to a different technology. The process used to make this determination involves breaking the technology into components, or layers, then examining whether any given component is a good open source candidate.

The starting point in this analysis is Yochai Benkler's three layers of a communications system. These are: the "physical" layer across which information travels, the "code" layer that makes the physical layer run, and the "content" layer of information.[69] The hardware-code-content paradigm provides a useful means of analyzing many technologies beyond software or the Internet. For example, in his book *The Future of Ideas*, Lawrence Lessig describes how those layers apply to various traditional modes of communication, ranging from Speaker's Corner in London, to the arts, books, and music.[70] In each area, it is easy to tease out different layers that may be either controlled or open.

After the appropriate layers have been identified, each layer must be examined to determine whether that layer is an open source candidate. In *Coase's Penguin*, Benkler concludes that a technology must possess two characteristics for open source or "peer production" to be feasible.[71] First, the project must offer "social-psychological rewards" that will attract collaborators.[72] Second, the project must be divisible into small parts, such that any individual collaborator's investment is small.[73] Benkler suggests three characteristics of divisibility: (1) the project is "modular," meaning that it can be broken into asynchronous components; (2) the modules are "fine-grained," meaning that each

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67. *Id*.
68. For further discussion of open source licensing, see *infra* Part III.B.4.
69. *See supra* notes 3–4 and accompanying text.
70. *See* LESSIG, *supra* note 3.
71. Benkler, *supra* note 5.
72. *Id*. at 379.
73. *Id*.

module is manageably small; and (3) there is a low cost to integrate the modules.[74]

Benkler's criteria are a good start. However, modularity, granularity, and social-psychological rewards are necessary, but not sufficient, criteria for open source production. This Article suggests that a viable open source model requires a particular community with three characteristics: (1) there must be a preexisting community with norms of sharing and collaboration in which the social-psychological rewards are rooted, (2) there must be authoritative voices within that community who add value to the rewards, and (3) there must be authoritative voices within the community who catalog and publish individual contributions to the project. Moreover, as David McGowan has argued, open source norms can only develop within a legal framework supported by certain license terms.[75] In particular, open source licenses must include covenants that run with the code to ensure that the code remains perpetually open.[76]

In the following subparts, this Article addresses these criteria as they might apply to biotechnology. This Article proceeds in reverse order, starting with an analysis of whether a typical biotechnology invention (for example, the Iogen bioengineered microbe) could meet Benkler's divisibility criteria. Then, assuming that the divisibility criteria could at least in part be met, this Article examines the norms of biotechnology in light of Benkler's social-psychological rewards criterion and my community criteria. Finally, this Article reviews the nature of open source licenses, and discusses whether such a licensing regime can apply to biotechnology.

2. The Layers and Granularity of a Bioengineered Fungus

The Iogen patent on a genetically engineered microbe will again serve as a useful example of how open source principles could map onto the development of biotechnology. The independent claims of Iogen's patent specify a genetically modified microbe with five components: (1) a microbial host, (2) a genetic construct having a specific promoter, (3) an enzyme secretion signal, (4) an enzyme coding region, and (5) the resultant increased production level of the target enzyme.[77] These components can be broken down into a hardware layer, several code layers, and a content layer.

74. *See id*.
75. *See* David McGowan, *Legal Implications of Open-Source Software*, 2001 U. ILL. L. REV. 241, 268–71 (2001).
76. *See id*.
77. '703 Patent, *supra* note 56.

The hardware layer is the microbial host. The microbial host can be any of several types of fungi,[78] though two strains of Trichoderma fungus are identified as particularly suitable hosts.[79] These strains are proprietary to Iogen.[80]

This first hardware layer represents an initial area in which open source biotechnology must diverge from open source software. The hardware layer for most open source software, at least at the user level, is relatively inexpensive and standardized; anyone can easily obtain a desktop computer on which to run Linux. Biotechnology is significantly different because the hardware layer typically is organic and the interaction between the hardware and code layers often is highly specialized and complex. As in the early days of desktop computing, there are many different, incompatible "platforms" on which code runs.

However, unlike desktop computing, there is as yet no technology for developing a common platform or even a common set of cross-platform communication protocols. Moreover, as illustrated by the Iogen patent's specification, the most appropriate hardware platform might be a proprietary strain that likely is subject to other intellectual property rights or contractual limitations on use. Therefore, the biotechnology hardware layer is not a strong open source candidate.

The "code" layers in the '703 Patent are the gene and DNA regions. Before considering whether these code layers can be open, however, one must first examine how the code is created. Again, these biological code layers are far more complex than computer code. The code layers in the '703 Patent — and in any biotechnology with layers of genetic code — cannot be created simply by typing on a keyboard.

A preliminary step to creating the code layers is to determine the DNA sequence of the target organism. Having established the DNA sequence, the next step is to determine which genes likely code for the desired proteins. The invention claimed in the '703 Patent relies on previously published DNA sequences of Trichoderma strains.[81] This represents a foundational, or "pre-code," layer of information that facilitates the production of the code layers.

There has been much written about whether gene sequence databases should be openly available.[82] In fact, it is fair to say that this question of open access has been the focus of most scholarship con-

78. *Id*. at Claim 1.

79. *Id*. at Column 10, Lines 54–65.

80. *Id*. at Column 10, Lines 63–64.

81. *See id*.

82. *See, e.g.*, Rebecca S. Eisenberg, *Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research*, 82 VA. L. REV. 1663 (1996); MAXWELL J. MEHLMAN & JEFFREY R. BOTKIN, ACCESS TO THE GENOME: THE CHALLENGE TO EQUALITY (1998).

cerning the nexus between emerging genetic technologies and intellectual property law. It seems clear that the pre-code layer of gene sequence information must be open if biotechnological development involving genetic engineering is to be open source.[83]

Whether or not the gene sequence information is obtained through open sharing or other means, the next step in creating the code layers is to isolate genomic DNA from the host fungal strain.[84] This requires the equipment and know-how to culture the fungus, crush and suspend the biomass, and precipitate, pelletize, and purify the DNA.[85] Therefore, although this layer is divisible, it is not very granular. Isolation of genomic DNA cannot yet happen in a hacker's garage.

After isolating the genomic DNA, the researcher must construct genomic libraries of the DNA. A genomic library is a set of clones containing different DNA fragments that together make up the genome of an organism.[86] This involves cutting the DNA into fragments through enzymatic digestion, and inserting the plasmids or phages into a host organism.[87] Again, this requires the equipment and know-how to create the clones — requirements that diminish granularity.

The third step in creating the code layer involves isolating clones in the genomic library that carry the genes that code for the desired protein, extracting the DNA from those clones, and creating vectors for splicing the desired genes into the host organism's DNA.[88] This process also requires the appropriate equipment and know-how. There

83. The Human Genome Project, through which widely dispersed and otherwise unaffiliated researchers sequenced the human genome, often is hailed as an excellent example of open source biotechnology. *See, e.g.*, *An Open Source Shot in the Arm?*, THE ECONOMIST TECH. QUARTERLY, June 12, 2004, at 17. Its history provides an interesting narrative of how a scientific community decides to make a product open source. For a discussion of how the Human Genome Project developed, see generally Kathy Hudson, *The Human Genome Project: A Public Good*, 12 HEALTH MATRIX 367 (2002).

However, many of the arguments concerning an open human-genome database may not be applicable to open source biotechnology in general. The debates tended to focus on normative questions relating to the ownership or control of a resource that arguably is the heritage of all humanity and how the common ownership of such a resource might impact questions of biodiversity, class conflict, and eugenics. *See, e.g.*, MEHLMAN & BOTKIN, *supra* note 82, at chs. 5–6; Dan W. Brock, *The Human Genome Project and Human Identity*, 29 HOUS. L. REV. 7 (1992); Alastair T. Iles, *The Human Genome Project: A Challenge to the Human Rights Framework*, 9 HARV. HUM. RTS. J. 27 (1996); Eric S. Lander, *Scientific Commentary: The Scientific Foundations and Medical and Social Prospects of the Human Genome Project*, 26 J.L. MED. & ETHICS 184 (1998); Allison Morse, *Searching for the Holy Grail: The Human Genome Project and Its Implications*, 13 J.L. & HEALTH 219 (1999); Mary Z. Pelias & Nathan J. Markward, *The Human Genome Project and Public Perception: Truth and Consequences*, 49 EMORY L.J. 837 (2000).

84. *See* '703 Patent, *supra* note 56.

85. The process is described in detail in Example 1 of the '703 Patent. *See id*.

86. *See* Oakridge Nat'l Lab., Human Genome Project Glossary, *at* http://www.ornl.gov/sci/techresources/Human_Genome/glossary/glossary_g.shtml (last modified Sept. 12, 2004).

87. *See* '703 Patent, *supra* note 56.

88. *See id*.

are numerous vector methods, each of which has different advantages and disadvantages.[89] The vectors then must be introduced into the host. In the '703 Patent, the method used is microprojectile bombardment, but other methods are available as well.[90] Given the complexities of producing each of these code layers, anything other than the foundational pre-code layers would be difficult to distribute for production in an open source environment. Thus, an open development system relating to the code layer of a biotechnology invention would require that the genetic code, the appropriate vector method, and the best method of vector introduction be readily available. This is in contrast to the relative simplicity of the code layer in computer software, in which code is just that — lines of coded programming language.

The "content" layer in the '703 Patent is the function performed by the bioengineered microbe, which, in this case, is the production of enzymes that efficiently digest biomass. This layer is easily identified, but is not highly granular. The enzyme could be synthesized by a method other than cloning a microbe, but probably not in commercially useful quantities. Even then, such synthesis would require the use of specialized starting materials, equipment and techniques that might be available only in a professional chemistry lab and might themselves be subject to proprietary rights. Thus, the content layer is not a likely open source candidate.

Finding divisibility and granularity in biotechnology, then, is no simple matter. However, at least some aspects of biotechnology could meet the divisibility requirement for open source production. In particular, the foundational pre-code layers underlying most biotechnology inventions — bioinformatics databases containing gene sequence data — could be broken into distributable components. As discussed in the next part, despite this possible candidate for open source production, the need for a compelling social-psychological reward system and an appropriate licensing framework remains problematic for the theoretical possibility of open source biotechnology.

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89. *See* Univ. Coll. London, Essential Techniques of Molecular Genetics, *at* http://www.ucl.ac.uk/~ucbhjow/b241/techniques.html (last visited Nov. 29, 2004).

90. *See* '703 Patent, *supra* note 56. Microprojectile bombardment is a method whereby particles of a substance (such as tungsten) are coated with the DNA desired to be introduced and shot into the membrane of target cells. *See* Paul Christou & Dennis McCabe, Particle Gun Transformation of Crop Plants Using Electric Discharge (ACCELL™ Technology), *at* http://www.nal.usda.gov/pgdic/Probe/v2n2/particle.html (last visited Nov. 29, 2004).

3. Social-Psychological Rewards and the Norms of Science

a. Classical and Neoclassical Views of the Norms of Science

Most of the scholarship relating to the biotechnology commons is based on the story of a relatively homogenous, open scientific community that has been co-opted by a pernicious advance of privatization.[91] For example, Rebecca Eisenberg's germinal article describes the classical view of the "Community of Science" norms formalized by sociologist Robert Merton.[92] Among the core scientific norms described by Merton was communalism, or the belief that scientific findings belong to the scientific community as a whole, so that they can be examined by the whole community, and so that future science can build on those findings.[93] These norms created a culture that looked askance at proprietary claims, such as patents, and efforts to keep information secret.[94] That culture, in turn, was reinforced by legal rules and practical working conditions that made it difficult to claim proprietary rights in basic research or to keep such research secret.[95] In fact, the scientific community's incentive structure, based on the peer recognition that comes with publication, rewarded openness.[96]

In Eisenberg's telling of the story, changing intellectual property laws have threatened these venerable Mertonian norms. In particular, pro-patent decisions such as *Diamond v. Chakrabarty*[97] provide incentives for researchers to keep research secret until a patent application is filed.[98] Where the law once supported the norm of disclosure, it now encourages a norm of strategic behavior.[99] Eisenberg suggests

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91. *See, e.g.*, JEREMY RIFKIN, THE BIOTECH CENTURY 38–48 (1998). Rifkin provides a simplified history of enclosure movements since the 1500's through the *Diamond* decision and concludes, "The international effort to convert the genetic blueprints of millions of years of evolution to privately held intellectual property represents both the completion of a half-millennium of commercial history and the closing of the last frontier of the natural world." *Id*. at 41. Rifkin's purpose, however, is not to promote a more open paradigm of biotechnology development, but rather to warn against the control over biological information that biotechnology patents provide. *See id*.

92. *See* Rebecca S. Eisenberg, *Proprietary Rights and the Norms of Science in Biotechnology Research*, 97 YALE L.J. 177 (1987); Paul David, *The Economic Logic of "Open Science" and the Balance Between Private Property Rights and the Public Domain in Scientific Data and Information: A Primer*, *in* NAT'L RES. COUNCIL, *supra* note 49, at 21 (explaining that the Mertonian norms of the "Republic of Science" can be summarized as CUDOS: communalism, universalism, disinterestedness, originality, and skepticism).

93. *See* Robert Merton, *The Normative Structure of Science*, *in* THE SOCIOLOGY OF SCIENCE 273–75 (1973); *see also* David, *supra* note 92, at 21.

94. *See* Eisenberg, *supra* note 92, at 184–95.

95. *See id*.

96. *See id*.

97. 447 U.S. 303 (1980).

98. *See* Eisenberg, *supra* note 92, at 216 (explaining that these incentives exist because early disclosure could trigger patent law's publication bar).

99. *See id*. at 195–200.

that this trend should be reversed by shrinking the availability of private rights in the biotechnology commons.[100]

Likewise, Arti Rai traces the history of molecular biology from its "highly theoretical, abstract roots" in the 1930's, during which the classical norms of science prevailed, to the present, when those norms are being challenged by the commercial interest in biotechnology.[101] Rai argues that changes in legal and economic opinion in favor of intellectual property rights in the 1970's, and the resultant changes in the law in the 1980's, significantly eroded the classical norms of science in molecular biotechnology.[102]

In a subsequent article, Rai and Eisenberg describe the trend of patenting upstream inventions by universities.[103] Rai and Eisenberg note that, given the choice, stakeholders in biomedicine often choose to dedicate upstream inventions to the public domain.[104] However, Rai and Eisenberg believe pressure by university technology transfer departments to proprietize intellectual property creates a collective action problem where individual actors will not unilaterally forgo intellectual property protection.[105] They suggest that the law should reflect "a system that distinguishes cases in which proprietary claims make sense" — in their view, those oriented toward downstream commercial applications — from cases in which proprietary rights do not make sense — in their view, those oriented toward upstream discoveries.[106] Since many upstream discoveries result from government-funded basic research, Rai and Eisenberg propose that funding agencies be given more latitude to determine whether it is in the public interest to allow private patent rights over inventions resulting from the funded research.[107]

J.H. Reichman and Paul Uhlir have expanded on Eisenberg's analysis, developing what I call a "neoclassical" view of the norms of science.[108] They observe that the norms identified by Merton are influenced by the structures in which science is conducted, as well as by

100. *See id*. at 229–31.

101. *See* Arti K. Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77, 88–115 (1999).

102. *See id*. ("Prior to the 1980's, [biomolecular research] was largely governed by the traditional norms of a relatively homogenous academic scientific community. . . . Beginning in 1980, the legal framework surrounding scientific research shifted dramatically. . . . This effort changed significantly the traditional norms of scientific research."). *Id*. at 88.

103. Arti K. Rai & Rebecca Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289 (2003).

104. *Id*. at 298.

105. *See id*. at 305.

106. *Id*. at 304.

107. *Id*. at 310.

108. J.H. Reichman & Paul F. Uhlir, *A Contractually Reconstructed Commons for Scientific Data in a Highly Protectionist Intellectual Property Environment*, 66 L. & CONTEMP. PROBS. 315 (2003).

the prospect of proprietary rights. "Big science," such as physics, space, and the earth sciences, is managed by the government, and the fruits of that work are kept in public domain depositories as a matter of public policy.[109] "Small science," such as molecular biology, is conducted by individual investigators or small research groups, and the resulting data is published in disaggregated sources.[110] The producers of scientific data in both categories may include government agencies, academic or non-profit institutions, and private businesses.[111]

Where government has funded scientific research, contractual clauses, coupled with long-held norms, have encouraged the disclosure of the results.[112] While the results may be disclosed in copyrighted journals or commercial databases, copyright principles designed to protect the public domain (for example, fair use, the originality requirement, and the idea/expression dichotomy), have helped preserve the principle of open access.[113] However, these protections of the information commons are threatened by the Bayh-Dole Act, which eases restrictions on the patentability of inventions developed with government-funded research. They are also weakened by rules that protect otherwise non-copyrightable databases, such as the Digital Millennium Copyright Act and the European Union Database Directive.[114]

Large-scale research conducted without public funding has been subject to similar changes in circumstances. Like government-funded research, the norms of science previously encouraged publication. Even if the results were published in proprietary journals or patent documents, the underlying data would fall into the public domain. The new digital content and database protections may remove from the public domain even this underlying research data.[115]

Reichman and Uhlir further discuss what they call the "informal zone" of smaller-scale research conducted without public funding.[116] Here, it is less clear that the Mertonian vision of universal scientific norms ever fully applied. The informal system of data exchange includes the various components of the data stream: not just the data itself, but also the associated know-how, individual skills, and per-

109. *See id.* at 322–23.
110. *See id.*
111. *Id.* at 325.
112. *Id.* at 334.
113. *See id.* at 336–41.
114. *See id.* at 342, 377–94; *see also supra* Parts II.B, II.F, and II.G.
115. *See* Reichman & Uhlir, *supra* note 108, at 377–94.
116. *Id.* at 405–06.

sonal connections that help produce meaningful results.[117] For example, a lab wishing to develop a genetic treatment to retard the replication of a particular virus needs not only data on the virus's genomic sequence and some papers about cloning, but also adequate viral sample stocks, seed stocks for carriers of the cloned DNA, and scientists and technicians capable of handling the biological materials and skilled at using the necessary equipment and computer databases. This information resides in the experience of the scientists and technicians who may have incentives to engage in strategic behavior to advance their careers or disadvantage rivals rather than make full disclosure.[118] In Reichman and Uhlir's view, the availability of additional proprietary rights for basic data will only encourage this kind of strategic behavior.[119]

Reichman and Uhlir's hope is to find some way to preserve the research commons against this encroachment. Although they recognize that the norms of science were never as clear-cut as Merton proposed, they retain the idealized vision of a community dedicated to the advancement of knowledge and the public good. They therefore propose that the scientific community adopt, and that the government encourage, a voluntary contractual system whereby scientific data would be deposited into networked, distributed electronic depositories, with rights of public access and use.[120] In this respect, their proposal is similar to the Creative Commons license typically employed in the open source software movement.[121] If any participant's data leads to a profitable derivative invention, the subsequent inventor could be required to pay some remuneration to the data's originator.[122]

b. The Norms of Science as Competition and Conflict

Under either the classical or neoclassical view, it is clear that the social-psychological reward system in science is generally complex. In reality, it is far more complex than either the classical or neoclassical views suggest. Many historians and sociologists of science now reject Merton's description of science as a cooperative enterprise and focus instead on the conflicts, rivalries, and strategic behavior of scientists and scientific institutions.[123]

117. *See id*. at 404–07; *see also* Sherry Brandt-Rauf, *The Role, Value and Limits of S&T Data and Information in the Public Domain for Biomedical Research*, *in* NAT'L RES. COUNCIL, *supra* note 49, at 67.

118. *See* Reichman & Uhlir, *supra* note 108, at 404–07.

119. *See id*.

120. *Id*.

121. *See id*. For a discussion of the Creative Commons license, see *infra* Part III.B.6.

122. *See* Reichman & Uhlir, *supra* note 108, at 435.

123. *See* Janet Hope, *Sociology of Science*, OPEN SOURCE BIOTECHNOLOGY PROJECT, *at* http://rsss.anu.edu.au/~janeth/Sociology.html (last modified Feb. 1, 2003) (noting that "dur-

For example, in his groundbreaking work *The Structure of Scientific Revolutions*, Thomas Kuhn argues that science does not typically progress in an orderly evolutionary fashion.[124] Rather, science rests on established paradigms, and the work of most individual scientists merely explores details of the existing paradigms within particular specialties.[125] Challenges to established paradigms are typically met with hostility unless individuals of sufficient skill or personality drive the paradigm shift.[126] Thus, far from a norm of openness or communitarianism, scientific research instead is rife with turf wars and gamesmanship.

In their book *The Golem: What Everyone Should Know About Science*, Harry Collins and Trevor Pinch describe paradigmatic examples of the failure, or absence, of Mertonian norms in science.[127] Collins and Pinch conclude that research communities are fractionated into specialties dominated by powerful personalities and supported by government funding streams focused on particular lines of inquiry. Further, research directed outside of these well-worn pathways is difficult, if not impossible, to pursue.[128] Once again, the norm is not openness and cooperation, but conformity and competition.

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ing the 1960's and 1970's — influenced by developments in the history and philosophy of science — sociologists of science began to take a more cynical view of competition and collaboration within scientific communities"); *see also* ULLICA SEGERSTRALE, DEFENDERS OF THE TRUTH: THE BATTLE FOR SCIENCE IN THE SOCIOBIOLOGY DEBATE AND BEYOND 333–47 (2000) (chronicling recent criticisms of the classical view of scientific objectivity).

124. THOMAS S. KUHN, THE STRUCTURE OF SCIENTIFIC REVOLUTIONS 160–73 (2d ed. 1970).

125. *See id*.

126. *See id*. Kuhn notes:

> Because the unit of scientific achievement is the solved problem and because the group knows well which problems have already been solved, few scientists will easily be persuaded to adopt a viewpoint that again opens to question many problems that had previously been solved. Nature itself must first undermine professional security by making prior achievements seem problematic. . . . Novelty for its own sake is not a desideratum in the sciences as it is in so many other creative fields.

Id. at 169.

127. HARRY COLLINS & TREVOR PINCH, THE GOLEM: WHAT EVERYONE SHOULD KNOW ABOUT SCIENCE (1993) (describing a number of colorful episodes of competition and strategic behavior in scientific research).

128. Collins and Pinch summarize the claims of two chemists, Martin Fleishmann and Stanley Pons, to have produced cold fusion in a test tube, as follows:

> Any claim to observe fusion (especially made in such an immodest and public manner [to the news media]) was bound to tread upon the toes of the nuclear physicists and fusion physicists who had already laid claim to the area. A vast amount of money, expertise, and equipment had already been invested in hot fusion programs and it would be naïve to think that this did not affect in some way the reception accorded to Pons and Fleischmann.

Id. at 74.

c. The Norms of Science and Social-Psychological Rewards

Under either the neoclassical or conflict views of the norms of science, it is clear that there has never been a "hacker" culture in the hard sciences. This is particularly true of biotechnology. Although there are some incentives to seek publication and awards, which encourage disclosure, the norms of biotechnology do not require the rapid exchange of information of the hacker culture. In fact, as Stephen Hilgartner notes, there are some cases of researchers choosing to delay publication to avoid helping a competing lab that is behind in its work.[129] Thus, "complex negotiations, replete with strategic gamesmanship and uncertainty, are routine in small-scale biomedical research."[130]

Further, the hacker culture is ill-suited to biotechnology because much unwritten, but vitally important, information resides in the background knowledge and skills of individual biotechnology researchers.[131] A computer hacker can work alone, in a basement or garage, with just a desktop computer and an Internet connection. Biotechnology "hacks," in contrast, require specialized equipment, the know-how and skill to handle the equipment and biological materials safely, and access to substantial bioinformatics databases.[132] The skill and knowledge of individual researchers and technicians is not always shared by competing institutions.[133] It is difficult to conclude that bio-

129. *See* Stephen Hilgartner, *Potential Effects of a Diminishing Public Domain in Biomedical Research Data*, *in* NAT'L RES. COUNCIL, *supra* note 49, at 133–34 ("[S]cientists do not simply publish everything that they produce; they engage in strategic maneuvers about who is going to get access to what data and materials under what terms and conditions. Publication is only one move (albeit an extremely important one) in an extremely complex process.").

130. *Id*.

131. *See* David, *supra* note 92, at 25.

132. *See id*. David states:

> [A] great deal of the scientific expertise available to a society at any point in time remains tacit, rather than being fully available in codified form and accessible in archival publications. It is embodied in the craft-knowledge of the researchers, about such things as the procedures for culturing specific cell lines, or building a new kind of laser that has yet to become a standard part of laboratory repertoire.

Id. *See also* Hilgartner, *supra* note 129, who writes:

> An isolated, single biological material sitting alone in a test tube is a useless thing; to be scientifically meaningful, it must be linked using labels and other inscriptions to source the sample and its particular characteristics. Moreover, to use the material, one needs a laboratory equipped with an appropriate configuration of people, techniques, instruments, and so forth.

Id. at 134.

133. *See id*. (describing how many laboratory tools are common to all laboratories, but that "some of the items — especially those toward the 'leading edges' of these evolving assemblages — are available only in a few places, or perhaps only in one place. These scarce and unique items can convey a significant competitive edge."). *But see* David, *supra*

technology possesses any clear norms that would support the social-psychological reward system needed for peer production to occur.

4. The Need for a Preexisting Community with Authoritative Voices

Benkler's social-psychological reward criterion is important, but that criterion cannot exist in a vacuum. It is crucial that such norms be part of a deeply held sentiment within an existing community. Open source communities do not appear *ex nihilo*. An open source community must develop from the bottom up; it cannot be imposed from the top down.

The open source software movement, for example, began when computers and software were still novelties confined primarily to universities and government.[134] There developed a community of hackers who reveled in sharing source code so that it could be tweaked and customized.[135] These internalized norms evolved into the broader culture of open source.

Further, open source communities are not truly egalitarian. In its more idealized forms, open source rhetoric evokes a community without class conflict. In reality, an open source community must have its own class system, as well as a central point (or at least central nodes), by which individual contributions are ranked. Both of these elements are essential to integrating individual contributions into a coherent commons and to establishing a basis for the social-psychological rewards that motivate peer production.

Both of these additional components of open source culture have been described by Eric Raymond, an early hacker and open source software proponent.[136] In his essay *Homesteading the Noosphere*,[137] Raymond notes that the open source culture is based on norms and customs adapted from the early hacker culture.[138] He observes that open source software hackers operate in a "gift culture" in which competitive success is measured by reputation among other hack-

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note 92, at 25 (noting that some circulation of this kind of embodied craft information occurs as post-doctoral students and newly trained researchers circulate among various labs).

134. *See* Open Knowledge, A Brief History of Free/Open Source Software Movement, *at* http://www.openknowledge.org/writing/open-source/scb/brief-open-source-history.html (last modified Dec. 26, 2000).

135. *See id*.

136. *See* Eric S. Raymond, Home Page, *at* http://www.catb.org/~esr/ (last modified Mar. 14, 2004).

137. Eric S. Raymond, Homesteading the Noosphere, Introductory Contradiction, *at* http://www.catb.org/~esr/writings/cathedral-bazaar/homesteading/ (last modified Aug. 24, 2000).

138. *See* Eric S. Raymond, Homesteading the Noosphere, Ownership and Open Source, *at* http://www.catb.org/~esr/writings/cathedral-bazaar/homesteading/ar01s04.html (last modified Aug. 24, 2000).

ers.[139] A good reputation is developed by imparting useful "gifts" to the community, in the form of contributions of code and bug fixes.[140] As Raymond notes, a gift culture arises only when there is no scarcity of essential resources, as scarcity requires rationing.[141] The essential resources of open source software, including disk space, computing power, and network bandwidth, are cheap and abundant, facilitating the gift culture.[142]

Raymond also observes that open source software projects require some locus of authority through which individual gifts are screened, recognized, and ranked.[143] Project "owners" recognize and integrate "official" patches into the software.[144] Unofficial or "rogue" patches that do not receive the imprimatur of the project's owners are considered untrustworthy and deliver few, if any, reputational rewards.[145]

Raymond's observations demonstrate that the cost of integrating granular contributions is not determinative, as Benkler suggests. Equally important is whether the integrator has sufficient *authority* within the community to attract contributions and to produce a coherent corpus that the community recognizes as canonical. Absent an authoritative integrator, peer production is unlikely to occur. There is little incentive to produce a granular contribution without either the assurance that it will become part of a functioning whole or the hope of obtaining the reputational rewards associated with acceptance into the "official" product version.

Further, the integrator must have some authority to screen contributions and define the canon of contributions that make up the whole work. Contributions that are completely non-functional, or even malicious, must be screened out before the corpus is released for community scrutiny. Otherwise, the cost of reviewing the product for further areas of modification and improvement will become prohibitively high for individual community members, and the product will lack any utility to end users.

Raymond notes several ways in which an integrator achieves such authority. The default authority figure is the project's founder.[146] Indeed, Raymond notes that the open source community's custom "does not even permit a *question* as to who owns the project" if the founder

139. *See* Eric S. Raymond, Homesteading the Noosphere, The Hacker Milieu as a Gift Culture, *at* http://www.catb.org/~esr/writings/cathedral-bazaar/homesteading/ar01s06.html (last modified Aug. 24, 2000).

140. *See id*.

141. *See id*.

142. *See id*.

143. *See* Raymond, *supra* note 138.

144. *See id*.

145. *See id*.

146. *See id*.

remains actively involved in its development.[147] Alternatively, the project's founder might "pass the baton" to a group of trusted successors.[148] Again, custom dictates that the founder's choice of successor is rarely challenged.[149] Finally, a later arrival can acquire ownership of a project after the founder or his chosen successors have abandoned it by publicly announcing an ownership claim, and then, without significant challenge from the community, exercising the functions of project owner.[150] Raymond views this process as analogous to Locke's theory of land tenure.[151] Thus, "owners" of open source projects are "homesteaders" in the "noosphere" ("the territory of ideas, the space of all thoughts").[152]

The Linux operating system is a prototypical example of how these dynamics work.[153] Linus Torvalds, the creator of the original Linux kernel, is recognized as the authoritative integrator of the Linux development community.[154] Torvalds has partially "passed the baton" of this role to Open Source Development Labs ("OSDL"), which is the "recognized center of gravity for Linux."[155] OSDL has attracted the participation of industry leaders such as IBM, Cisco Systems, and Intel, which use the Linux operating system to varying degrees.[156] Linux developers can submit projects to OSDL, which will test and certify them as appropriate for enterprise use.[157]

One implication of Raymond's observations is that "open source" does not mean "open commons." Indeed, one might as well substitute "information commons," which is used by most information commons theorists, for "noosphere." Open source then could be viewed as a means of managing a common pool resource through a hybrid private

147. *Id*. (emphasis in original).

148. *Id*.

149. *See id*.

150. *See id*.

151. *See* Eric S. Raymond, Homesteading the Noosphere, Locke and Land Title, *at* http://www.catb.org/~esr/wirtings/cathedral-bazaar/homesteading/ar01s05.html (last modified Aug. 24, 2000).

152. *Id*.

153. *See* David McGowan, *The Legal Implications of Open-Source Software*, 2001 U. ILL. L. REV. 241, 268–71 (2001). McGowan describes a "hierarchical aspect" to Linux development, and notes that Red Hat told investors that the Linux kernel was controlled by Linus Torvalds and a small group of engineers working with him. *Id*. at 268. McGowan notes the similar example of the open source Perl scripting language, which has been described as a "constitutional monarchy" run by the project's maintainer. *Id*. at 269.

154. *See* Eric S. Raymond, The Cathedral and the Bazaar, Necessary Preconditions for the Bazaar Style, *at* http://www.catb.org/~esr/writings/cathedral-bazaar/cathedral-bazaar/ar01s10.html (last modified Sept. 11, 2000).

155. OSDL, About OSDL, *at* http://www.osdl.org/about_osdl/ (last visited Nov. 29, 2004).

156. *See id*.; *see also* OSDL, OSDL Members, *at* http://www.osdl.org/about_osdl/members/ (last visited Nov. 29, 2004).

157. *See* OSDL, *supra* note 155.

property/collective management approach. In fact, most successful open source communities are capable of effective collective-action responses to common pool resource problems. They tend to have a relatively small number of key players (the project "owners") who share the interests of the hacker culture and have repeated, visible, long-term interactions with other members of the community.[158]

In another sense, Raymond's description of how the gift culture typically affects the way open source developers stake claims to new ground in the software commons resembles the anti-commons theorists' description of how patents clutter the biotechnology landscape. Development proceeds by punctuated incrementalism: after a new project (for example, an operating system) is opened, developers fill in the gaps through incremental improvements until the next major project is opened.[159] Occasionally, a highly successful project becomes a "category killer," because there is no significant remaining reputational reward in the area covered by that project.[160] Thus, most development is not ground-breakingly novel, but rather offers modest improvements over what existed previously. The same is also often true of development based on patent rent-seeking.

5. The Penguin's Genome — Open Source Culture and Biotechnology

With each of the critical points of open source culture discussed above, there are substantial questions about whether open source could be applied to biotechnology development. As discussed in Part III.B.3.a above, there are some norms favoring openness and sharing of information in the sciences. These norms spill over into biotechnology, particularly in the academic community. Biotechnology development, however, requires a far more complex web of inputs than does writing computer code.

The interchange between commercial and academic biotechnology has been a vital component of biotechnology's growth. While a computer operating system or software application can be developed in a garage with a handful of cheap, readily available hardware and software tools, biotechnology development demands access to bioinformatic data, equipment, and know-how beyond the reach of a base-

158. *See* Robert C. Ellickson, *Law and Economics Discovers Social Norms*, 27 J. LEGAL STUD. 537, 538 (1998); ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 88–89 (1990); Robert D. Cooter, *Structural Adjudication and the New Law Merchant: A Model of Decentralized Law*, 14 INT'L REV. L. & ECON. 215, 218–19 (1994).

159. *See* Eric S. Raymond, Homesteading the Noosphere, Global Implications of the Reputation-Game Model *at* http://www.catb.org/~esr/writings/cathedralbazaar/homesteading/ar01s12.html (last modified Aug. 24, 2000).

160. *See id*.

ment hacker. Many of these critical pieces of data, technology, and knowledge have been developed in a structured environment supported by venture capital and intellectual property rights, rather than in a more open academic setting.[161]

Moreover, even within the academic science community, the norm of openness and sharing is circumscribed by the payoffs for keeping some critical information close to the vest.[162] Therefore, it would be difficult to evolve a robust open source culture from the bottom up in biotechnology. If patent protections are weakened or patents become more difficult to obtain, many important players are likely either to exit the game or shift to a strategy of secrecy. Either result would erode the biotechnology research commons.

In addition, biotechnology, like other natural sciences, has an existing social hierarchy that is unlikely to be displaced by peer-production communities. For the biotechnology scientist, reputational rewards come from such sources as peer-reviewed publications, funding awards and other prizes, presentations at professional conferences, titles, promotions, and tenure. This reward system is supported by an entrenched network of recognized prestige publications, conferences, and institutions. In contrast, no such institutional reward network existed for the hackers who were the fathers of open source. The prestige arising from a good hack came informally from within the ranks of the hackers rather than from formal established sources.

It could be argued that the existing prestige system in the biological sciences provides a foundation for an open source culture. The purpose of professional journals and conferences, after all, is to make information available so that it can be used, debated, and modified by the community. Articles and presentations in prestige outlets, however, are not analogous to source code hacks. A prestige publication takes months, if not years, to produce. The subject of a prestige publication typically is carefully selected not only for its potential contribu-

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161. *See* Robert Cook-Deegan, *The Urge to Commercialize: Interactions Between Public and Private Research Development*, *in* NAT'L RES. COUNCIL, *supra* note 49, at 87. Cook-Deegan notes that over $3 billion was spent by genomics firms and major pharmaceutical firms on genomics research and development in the year 2000, while government and non-profit funding amounted to $1.5 billion. *Id*. at 91–92. *See also* SHELDON KRIMSKY, BIOTECHNICS & SOCIETY: THE RISE OF INDUSTRIAL GENETICS 33–35 (1991) (stating that in a 1984 study, corporate capital, venture capital, public equity offerings, and private partnerships were the principal means of financing new biotechnology companies). Krimsky provides an account of how the biotechnology industry developed in four phases: a rapid growth phase financed primarily by venture capital; a stabilization phase in which some of the early companies began funding their own research and development; a large-scale investment phase, in which multinational pharmaceutical companies purchased interests in or entered into alliances with smaller biotechnology companies; and a winnowing phase, in which weaker firms left the market and consolidation occurred through mergers and acquisitions. *See id*. at 37–42.

162. *See* Hilgartner, *supra* note 129.

tion to the field, but also for its prestige potential. The barriers to entry into key publishing venues are high. Often, only those with the educational and social credentials deemed necessary by the publishing gatekeepers are admitted. Finally, publishing decisions tend to be conservative. Researchers often do not want to take controversial positions, and publishers often do not want to publish them. The culture of prestige publications thus discourages experimentation with reigning paradigms.[163]

In contrast, peer production of computer source code is far more organic, rapid, and experimental. Although there is a central arbiter of what becomes part of the canon, there is no pre-publication screen based on external credentials, entrenched paradigms, or review panels. Anyone with an Internet connection can publish. Furthermore, the pace of publication is relatively rapid; new hacks often appear within hours of the original code's publication.

Finally, none of the discussions of the norms of science and biotechnology thus far have adequately addressed the way biotechnology research is heavily supported by venture capital. In the Mertonian paradigm, basic research was conducted by government-funded, academically-based projects, and commercialization was accomplished by industry. The situation in biotechnology is much more fluid. A significant amount of basic research is conducted by small, venture-backed private firms.[164] The venture capitalists that finance these firms depend on intellectual property protections to secure their investments. A typical model begins with upstream patents on research tools or other basic research garnering early returns from an emerging firm.[165] These early returns support additional funding, which hopefully leads to a profitable end product and acquisition by a larger pharmaceutical company.[166] Without intellectual property protection at crucial developmental milestones, this funding would evaporate, depleting the biotechnology commons.[167]

Thus, questions about the norms of openness in biotechnology research and the relatively distributed nature of authority within the existing biotechnology community might make the prospect of open source biotechnology a distant one.

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163. *See* KUHN, *supra* note 124; COLLINS & PINCH, *supra* note 127.

164. *See* Tom D'Alonzo, *Perspectives from Different Sectors: Small Biotechnology Company*, *in* NAT'L RES. COUNCIL, INTELLECTUAL PROPERTY RIGHTS AND THE DISSEMINATION OF RESEARCH TOOLS IN MOLECULAR BIOLOGY 57, 64–66 (1997).

165. *See id*.

166. *See id*.

167. *See id*. As D'Alonzo states, "[A] very important consideration [in a potential acquisition] is, what do you own, what will we have a right to, and will we have the freedom to operate?" *Id*. at 66.

6. Open Source Biotechnology and the Licensing Environment

As David McGowan has observed, the allocation of rights through license terms is key to open source production.[168] The General Public License ("GPL") is a prototypical example of such licenses, and is frequently employed in open source software projects.[169] The GPL permits the licensee to create derivative works and redistribute the source code of the licensed software, provided that the modified or redistributed product also is offered under the GPL.[170] Similar licenses are available under the Creative Commons project.[171] Although Creative Commons licenses allow for more flexibility in choosing license terms, including a term that would prohibit the creation of derivative works, the popular "Attribution," "Noncommercial," and "Share Alike" versions of the Creative Commons license allow the licensee to create and distribute derivative works.[172]

Even in the context of open source software, it is unclear whether a GPL or Creative Commons type of license would be enforceable against downstream parties who are not in privity with the originator of the underlying work.[173] It is even less clear whether a similar model could be adapted to biotechnology.

The HapMap project, for example, is an effort to create a haplotype[174] map of the human genome, which could be used to identify

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168. McGowan, *supra* note 75, at 289; *see also* James Boyle, *The Second Enclosure Movement and the Construction of the Public Domain*, 66 LAW & CONTEMP. PROBS. 33, 64 (2003) (stating that "the thing that makes open-source software work is the General Public License"); Chander & Sunder, *supra* note 8, at 1360–63 (discussing the effect of GPL and Creative Commons licenses on the biotechnology information commons).

169. *See, e.g.*, GNU Project, GNU General Public License, *at* http://www.gnu.org/copyleft/gpl.html (last visited Nov. 29, 2004).

170. *See id*. The GPL has sometimes been described as a "viral" license out of the fear that its terms will "infect" proprietary components being used alongside GPL licensed components, forcing the overall project to be distributed under the terms of the GPL as well. *See, e.g.*, Phil Albert, *The GPL: Viral Infection or Just Your Imagination*, LINUX INSIDER, May 25, 2004, *available at* http://www.linuxinsider.com/story/33968.html.

171. *See* Creative Commons, Licenses Explained, *at* http://creativecommons.org/learn/licenses/ (last visited Nov. 29, 2004).

172. *See id*. Chander and Sunder provide an empirical breakdown of Creative Commons license choices, revealing that only one percent of Creative Commons licensors prohibit any kind of derivative works, although most require restrictions on commercial use. *See* Chander & Sunder, *supra* note 8, at 1361–63. For a discussion of how the Creative Commons license facilitates the application of open source principles to works other than software, see Jonathan Zittrain, *New Legal Approaches in the Private Sector*, *in* NAT'L RES. COUNCIL, *supra* note 49, at 172–73.

173. *See, e.g.*, McGowan, *supra* note 75, at 289–302.

174. Haplotypes are the set of single nucleotide polymorphisms (genetic variations on the level of individual bases) along a region of a chromosome. *See* International HapMap Project, What is the HapMap?, *at* http://www.hapmap.org/whatishapmap.html.en (last modified Aug. 26, 2004).

variations that may relate to diseases such as cancers.[175] The HapMap license prohibits patent claims based on data obtained from the HapMap database, and further prohibits publication of otherwise nonpublic data obtained from the database except to parties who have also agreed to the HapMap license.[176] The HapMap license raises several troubling problems beyond those presented by a typical open source software license.

The GPL or Creative Commons license largely regulates activities that are directly related to copyright (creation of derivative works and distribution), and each user of the underlying work or derivative works accepts the terms of the license. The HapMap license, in contrast, goes beyond any right granted under intellectual property law and purports to restrict a licensee's freedom to file for patent protection or to publish factual data that in itself is not protected by copyright.[177] Nothing in the Patent Act would suggest that a patent could be invalidated because some of the underlying data was derived from a database in violation of the database's terms of use. Thus, it is unlikely that the HapMap license provides any meaningful remedy once a patent has been filed. Similarly, once data has been published in violation of the license terms, the horse will have left the barn. Since the HapMap project is a nonprofit venture, any damages from such a contractual breach are likely to be highly speculative.

The HapMap example highlights a key difference between open source licenses for software and biotechnology. Whereas software primarily is a creature of copyright, biotechnology primarily is a creature of patent. Because of the nature of derivative works, which imply separate ownership rights in the underlying work and the "new" portions of the derivative work, it is easy to imagine enforceable license terms that regulate distribution of derivative works and run with the copyright.

Patent law has no similar concept. If an inventor is able to meet all the requirements of patentability and is granted a patent, she (or her assignee) is the sole owner of her invention. It is true that, if the invention is an incremental improvement over the prior art, it might be impossible to practice the invention without obtaining licenses for the prior art. However, the owners of the patents in the prior art have

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175. *See* International HapMap Project, About the International HapMap Project, *at* http://www.hapmap.org/abouthapmap.html (last modified Feb. 6, 2004).

176. *See* International HapMap Project, Registration for Access to the HapMap Project Genotype Database, *at* http://www.hapmap.org/cgi-perl/registration#bottom (last visited Nov. 29, 2004).

177. *See id*. at ¶ 2 (Terms and Conditions). The Creative Commons Project recently announced a proposal to begin creating license terms for a "science commons," but the project remains in the exploratory stage. *See* Creative Commons, Projects: Proposal to Explore a Science Commons, *at* http://creativecommons.org/projects/science/proposal (last visited Nov. 29, 2004).

no say in whether the inventor, or any licensees of the inventor, can make further improvements to the art. Thus, "open source" licenses in biotechnology must reach beyond intellectual property law and create new contractual restrictions.[178]

Paradoxically then, in order to foster a more open biotechnology commons, the open source license must establish a contractual norm favoring proprietary rights *beyond* those available under current intellectual property law. Perhaps such contractual terms will be supplemented by DRM techniques that limit redistribution of database information except to validated users. Such restrictive license terms and controls likely will be adopted by others who want to lock up their biological code without any concern for the information commons. If the norm of openness does not take deep root in the biotechnology community, the adoption of restrictions would exacerbate the anti-commons effect. Thus, the translation of open source licensing concepts to biotechnology creates its own problems.

IV. The Public Domain, the Idealized Information Commons, and Open Source Biotechnology

In Part III, this Article concluded that open source principles would not easily transfer to biotechnology. Although there are examples of open source biotechnology projects, including BIOS[179] and the HapMap project,[180] there are still practical and cultural barriers to general open source development in biotechnology. These hurdles could possibly be overcome through a combination of internal lobbying, public pressure, and norm-enforcing law. However, before such steps are taken, one must first determine whether such an effort *should* be made. This normative question of whether biotechnology should use an open source model has, in many ways, remained unexamined in the current debates over the biotechnology "patent thicket" or anticommons. The assumption is that biotechnology is a paradigmatic information commons, and that it is best to keep the commons open. In other words, the normative question is obscured by commons rhetoric.

The commons metaphor has become so ingrained in intellectual property scholarship — particularly concerning new technologies and the Internet — that it arguably has achieved the status of a self-

178. *See* Robin C. Feldman, *The Open Source Biotechnology Movement: Is it Patent Misuse?*, SOC. SCI. RES. NETWORK ELECTRONIC LIBR. (May 10, 2004), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=545082 (suggesting that antitrust patent misuse claims could arise as a result of such provisions, although she argues that such claims should fail).

179. *See supra* note 18.

180. *See supra* notes 175–177 and accompanying text.

evident meta-narrative for all debates about proprietary rights. Commons rhetoric relating to intellectual property was fueled by the heady promise of the Internet's rapid growth during the mid-1990's.[181] Lawrence Lessig treats the idea of a commons as intrinsic to the Internet: "It is commonplace to think about the Internet as a kind of commons. . . . By a commons I mean a resource that is free. Not necessarily zero cost, but if there is a cost, it is a neutrally imposed or equally imposed cost."[182] Lessig extends this connection to open source software: "Open source, or free software, is a commons: the source code of Linux, for example, lies available for anyone to take, to use, to improve, to advance."[183]

The ties between commons rhetoric and the Internet's boom days have resulted in a reflexive response to any burst of technological growth. Information theorists seem to default reflexively to the commons metaphor and the open source model when confronted with developing technologies. However, the commons metaphor does not apply neatly to information and innovation. As it is typically applied to intellectual property and open source development, the commons metaphor is an uneasy fusion of Enlightenment concepts of the public domain, aspects of common pool resource management theory, and aspects of public goods theory.

In the next sections, this Article will unpack the complex roots of this seemingly simple metaphor. This Article first reviews the concept of the public domain in intellectual property law. Next, it discusses how information commons theory has adopted some older modernist elements of the public domain concept. Finally, this Article suggests that a more accurate non-foundationalist understanding of "information" robs the information commons metaphor of much of its descriptive force.

A. The Public Domain and the Commons

In U.S. law, the concept of a public domain is associated with the balance struck by the intellectual property clause of the U.S. Constitution between the need to provide incentives for private development and the desire to promote the public interest through openness.[184] There is little direct evidence of what the intellectual property clause meant to the Framers. James Madison's notes of the Constitutional Convention record that the clause was adopted without debate.[185] Ed-

181. *See* Chander & Sunder, *supra* note 8, at 1334 (claiming that "cyberlaw scholars have embraced, perhaps inadvertently, a kind of libertarianism for the Information Age").

182. Lawrence Lessig, *The Architecture of Innovation*, 51 DUKE L.J. 1783, 1788 (2002).

183. *Id*.

184. U.S. CONST. art. I, § 8, cl. 8.

185. THE RECORDS OF THE FEDERAL CONVENTION 509–10 (Max Farrand ed., 1911).

ward Walterscheid has suggested that the clause was a means of ensuring that the commerce power would be exercised to promote the progress of science and the useful arts specifically through the grant of limited monopolies.[186] Walterscheid bases this conclusion primarily on the fact that the intellectual property clause contains this specific limitation rather than a statement of general principles.[187] Other commentators suggest that the clause was patterned after the British Statute of Monopolies and Statute of Anne.[188]

More recently, Thomas Nachbar has argued that the intellectual property clause simply presents one possible form of regulating intellectual property — the grant of exclusive rights — but does not limit Congress's ability to regulate intellectual property through other enumerated powers, such as the commerce clause.[189] Nachbar fails to find any "constitutional norm," or "a rule required by and even inherent in the form of government adopted in the Constitution," that would prohibit Congress from creating other species of exclusive rights through the commerce power.[190]

None of these analyses of the intellectual property clause, however, adequately address the importance of the concept of the public domain. The intellectual property clause's reference to "science" and the "useful arts" suggests that the clause is not merely concerned with trade regulation. Rather, the clause is rooted in Enlightenment views about knowledge and scientific progress.

The Framers lived during a time when "science" encompassed far more than the term signifies today.[191] Today science is defined by its methodology. Something is considered science only if it follows a particular method of reasoning that produces falsifiable results.[192] The Enlightenment view of science was far broader. It encompassed all knowledge, including metaphysics, and was rooted in the concept of Natural Law.[193] The goal of this science, as conceived during the Sci-

186. *See* Edward C. Walterscheid, *To Promote the Progress of Science and the Useful Arts: The Background and Origin of the Intellectual Property Clause of the United States Constitution*, 2 J. INTELL. PROP. L. 1, 33–34 (1994).

187. *See id.* at 33.

188. *See* Tyler T. Ochoa & Mark Rose, *The Anti-Monopoly Origins of the Patent and Copyright Clause*, 84 J. PAT. & TRADEMARK OFF. SOC'Y 909 (2002).

189. *See* Thomas Nachbar, *Intellectual Property and Constitutional Norms*, 104 COLUM. L. REV. 272 (2004).

190. *See id.* at 317–61.

191. For a brief discussion of the development of the term "scientific" from Aristotle, through the Enlightenment, to modernity, see Dana Dalrymple, *Scientific Knowledge as a Public Good: Contributions to Innovation and the Economy*, *in* NAT'L RES. COUNCIL, supra note 49, at 37–38.

192. *See id.* at 35 (stating that "[s]cientific knowledge, in particular, is organized in a systematic way and is testable and verifiable").

193. *See* I. BERNARD COHEN, REVOLUTION IN SCIENCE 174 (1985) (claiming that "[m]en and women everywhere saw a promise that all of human knowledge and the regulation of

entific Revolution, was to discover truth. Not only the truth of particular factual propositions, but also of the metaphysical structure upon which those propositions were thought to rest.[194] The "progress" of science was the progressive unveiling of the Natural Law.

This broad Enlightenment understanding of science underlies the Framers' concept of the public domain. This concept of a Natural Law that cannot be possessed by anyone animates the Jeffersonian sentiment frequently quoted by advocates of an open information commons. In his famous letter to Isaac McPherson, Jefferson makes this link between Natural Law and the public domain explicit:

> If nature has made any one thing less susceptible than all others of exclusive property, it is the action of the thinking power called an idea. . . . That ideas should freely spread from one to another over the globe, for the moral and mutual instruction of man, and improvement of his condition, seems to have been peculiarly and benevolently designed by nature, when she made them, like fire, expansible over all space, without lessening their density at any point, and like the air in which we breathe, move, and have our physical being, incapable of confinement or exclusive appropriation. Inventions then cannot, in nature, be a subject of property.[195]

Curiously, few commentators have explored this link between the public domain and Enlightenment Natural Law. For example, although James Boyle recognizes that the Framers "had been nurtured on the philosophy of the Scottish Enlightenment," he focuses on how this created antipathy towards monopolies.[196] Boyle argues that it was primarily this distrust that drove the line between which intellectual creations would be public and which would be subject to patent or copyright.[197] Edward Lee has argued that the term "public domain" has served in judicial opinions as a public property concept that limits private property rights, including intellectual property rights.[198] In

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human affairs would yield to a similar rational system of deduction and mathematical inference coupled with experiment and critical observation. The eighteenth century became 'preeminently the age of faith in science.'").

194. *See id*. at 77–90.

195. Letter from Thomas Jefferson to Isaac McPherson (Aug. 13, 1813), *in* 6 THE WRITINGS OF THOMAS JEFFERSON 175, 180–81 (H.A. Washington ed., 1861).

196. *See* Boyle, *supra* note 168, at 57.

197. *See id*.

198. *See* Edward Lee, *The Public's Domain: The Evolution of Legal Restraints on the Government's Power to Control Public Access Through Secrecy or Intellectual Property*, 55 HASTINGS L.J. 91, 106 (2003).

either case — the antipathy towards monopolies or the recognition of public property in ideas — there are underlying normative concepts about Natural Law as well as utilitarian concerns about the deadweight costs of monopolies.

Notwithstanding the utilitarian focus of much historical scholarship about the public domain, the Jeffersonian Natural Law concept is evident in contemporary discussions of copyright and patent law. For example, Professor Melville Nimmer stated in a foundational copyright treatise that facts of nature are not copyrightable because "[i]f anyone may claim authorship of facts, it must be the Supreme Author of us all. The discoverer merely finds and records. He may not claim that facts are 'original' to him . . . ."[199] Likewise, a Jeffersonian public domain is reflected in patent law's prohibition against patents on "[t]he laws of nature, physical phenomena, and abstract ideas."[200] As *Diamond v. Chakrabarty* makes clear, a composition of matter is not ineligible for patent protection merely because it derives from a natural living organism, such as a genetically engineered bacterium.[201] However, at some point a line is drawn. Natural laws, such as the law of gravity, cannot be patented.[202] Nature is "free to all men and reserved exclusively to none."[203]

However, the Enlightenment concept of Natural Law as public domain has not remained unchallenged. In fact, much contemporary scholarship is critical of any concept of a public domain that refers to a preexisting reality. The belief that ideas exist independent of those who hold them is discounted as a Platonic fallacy.[204] Facts, the argument goes, are always colored by the researcher's interpretive lenses of methodology, perception, theory, or bias.[205] Researchers, in essence, are "composing their facts as they go along."[206]

Other recent scholarship describes the public domain in both normative and utilitarian terms. The normative view of the public domain is consistent with the Jeffersonian tradition: the public domain is seen as naturally open to all and a necessary adjunct to free expression.[207] However, overlaying this traditional normative explanation is a new utilitarian rationale: the public domain facilitates technological

199. Melville B. Nimmer, *The Subject Matter of Copyright Under the Act of 1976*, 24 UCLA L. REV. 978, 1016 (1977).

200. Parker v. Flook, 437 U.S. 584, 598 (1978). *See supra* note 24 and accompanying text.

201. *See* Diamond v. Chakrabarty, 447 U.S. 303, 310 (1980); *supra* Part II.A.

202. *Id*. at 309.

203. *Id*. (quoting Funk Bros. Seed Co. v. Kalo Inoculant Co., 333 U.S. 127, 130 (1948)).

204. *See* Jessica Litman, *The Public Domain*, 39 EMORY L.J. 965, 996 (1990).

205. *See id*.

206. *Id*.

207. *See* Yochai Benkler, *Free as the Air to Common Use: First Amendment Constraints on Enclosure of the Public Domain*, 74 N.Y.U. L. REV. 354, 361–62 (1999).

evolution or, in Schumpeterian language, creative destruction.[208] Enclosure of the public domain is bad because enclosure stifles free speech.[209] An open public domain is good because openness allows others to refine preexisting work and evolve new works.

These new ways of understanding the public domain have some merit. As discussed in Part III.A above, the evolutionary metaphor has worked magnificently for certain types of open source software development. Furthermore, as discussed in Part IV.C, it is important to acknowledge that information is always processed and interpreted by the recipient. Indeed, these concepts of evolution and information processing are particularly powerful when evaluating open source as a model for biotechnology. The practice of biotechnology is an exercise in guided evolution, and its products necessarily involve transformative information — information that changes the physical system receiving the information.

Despite this new scholarship, the syncretistic fusion of the Jeffersonian public domain with commons theory continues to dominate discussions about the biotechnology commons. As Chander and Sunder observe, "progressive" intellectual property scholars, who tend to view open source methods as a means of preserving the information commons, cling to a "romantic" view of the public domain, which is "celebratory, even euphoric, about the emancipatory potential of the commons" and yet is "naïve, idealistic, and removed from reality."[210] In the next section, this Article suggests how a more current understanding of information might support a more realistic approach to management of the biotechnology commons.

B. Constructing the Information Commons

A second component for understanding the concept of an information commons is the development of common pool resource management theory. The "commons" metaphor usually is traced back to an article by Garrett Hardin in *Science*, in which he portrayed the

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208. *See id*. at 362 (1999) ("The public domain is the range of uses of information that any person is privileged to make absent individualized facts that make a particular use by a particular person unprivileged."); Litman, *supra* note 204, at 1023 (arguing that the public domain "furnishes a crucial device to an otherwise unworkable system by reserving the raw material of authorship to the commons, thus leaving that raw material available for other authors to use"). With respect to Schumpeter's concept of "creative destruction," see JOSEPH A. SCHUMPETER, CAPITALISM, SOCIALISM AND DEMOCRACY (1975).

209. *See, e.g.*, Benkler, *supra* note 207.

210. Chander & Sunder, *supra* note 8, at 1331–41. Chander and Sunder argue that the romantic view of the commons is unrealistic because the prototypical commoner is not representative of the population that might benefit from the commons. In particular, "differing circumstances — including knowledge, wealth, power and ability — render some better able than others to exploit the commons." *Id*. at 1341.

now-familiar metaphor of open grazing lands that are rapidly depleted by self-interested herdsmen.[211]

Hardin's metaphor concerns the use of common pool resources. A common pool resource is one that is effectively non-excludable.[212] Excludability refers to the ease with which use of a good can be limited.[213] Typically, a common pool resource is non-excludable because of its size or lack of natural boundaries, for example, the ocean.[214] Hardin's concern was how common pool resources could be allocated in the face of steep world population growth.[215] Hardin's metaphor rapidly spread throughout the field of environmental science, and subsequently was adopted in legal and economic scholarship about real property.[216]

By the mid-1970's, Hardin's metaphor had been adopted in intellectual property scholarship, from which it proliferated to become arguably the central symbol in debates about the public domain.[217] Information, the analogy goes, is like a common pool resource because it is non-excludable. Once an idea becomes publicly available, it is difficult to exclude others from sharing the idea. Therefore, it is possible to think of intellectual property law's public domain as a part of an information commons.[218]

However, according to information commons theory, information is different from typical common pool resources because it is non-rival as well as non-excludable.[219] Rivalry refers to the extent to which use of a good diminishes it. Drawing on Jefferson's concept of the public domain, information commons theorists hold that information is non-rivalrous because an infinite number of people can simul-

211. Garrett Hardin, *The Tragedy of the Commons*, 162 SCI. 1243 (1968).

212. *See* ELINOR OSTROM, GOVERNING THE COMMONS 30 (1990).

213. *See id*.

214. *See id*.

215. *See* Hardin, *supra* note 211.

216. As commons theorist Elinor Ostrom has observed, three general approaches to the management of common pool resources emerged from Hardin's thesis: the "leviathan" solution, which posits that a commons should be managed by external governmental control; the "privatization" solution, which holds that private property rights and private bargaining will result in efficient allocation of a commons; and a "collective management" approach, in which commons users reach agreement about how best to collectively manage the commons. *See* OSTROM, *supra* note 212, at 8–18.

217. *See* Chander & Sunder, *supra* note 8, at 1332–34.

218. *See, e.g.*, Litman, *supra* note 204, at 968 (describing the public domain as a "commons that includes those aspects of copyrighted works which copyright does not protect").

219. *See* Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 TEX. L. REV. 989, 994–95, 1045 (1997); Dalrymple, *supra* note 191, at 43, 48 (stating that "disembodied pure knowledge" is one of the few "pure" public goods and that "[s]cientific knowledge in its relatively pure form is . . . the epitome of a global public good").

taneously think the same idea without diminishing the idea's content.[220]

Because information is non-rival under the accepted information commons theory, there is no need to allocate its use. There is no danger of a tragedy of the commons, because the commons cannot be overgrazed. Intellectual property rights are not necessary to preserve the commons. At best, intellectual property rights are useful to encourage some kinds of innovation; at worst, intellectual property is an artificial barrier to the commons.[221]

Under this conception, information fits the paradigm of a public good.[222] A public good is one that is non-rival in consumption as well as non-excludable.[223] A classic example of a public good is a street sign: once a street sign is in place, it is practically impossible to exclude anyone from viewing it and, no matter how many people view it, the sign's message will not wear out.[224]

Thus, information commons theory fuses the Enlightenment view of the public domain with common pool resource management theory. This model of an information commons animated the open source software movement with spectacular results. However, this now-classical information commons metaphor may be too simplistic to be of any real value for biotechnology. In particular, the kind of information that is important to biotechnology possesses aspects of rivalry that make a truly open information commons infeasible. This Article will now discuss the definition of "information" and how that definition relates to information commons theory.

C. Deconstructing the Information Commons

The information commons metaphor concerns information as an abstract concept. It hearkens back to the Enlightenment concept of Natural Law, in which information is pictured as something that exists independent of any economic, social, or biological structure. This

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220. *See, e.g.*, Boyle, *supra* note 168, at 33, 41–42. Boyle notes:

> Unlike the earthly commons, the commons of the mind is generally 'non-rival' . . . a gene sequence, an MP3 file, or an image may be used by multiple parties; my use does not interfere with yours . . . this means that the threat of overuse of fields and fisheries is generally not a problem with the informational or innovational commons.

Id.

221. *See* Lemley, *supra* note 219, at 996–98.

222. *See* Dalrymple, *supra* note 191, at 36.

223. *See* Lemley, *supra* note 219, at 994–95; David, *supra* note 92, at 20.

224. *See* Inge Kaul, *What is a Public Good?*, LE MONDE DIPLOMATIQUE, June 2000, *available at* http://mondediplo.com/2000/06/15publicgood. Other classic examples are lighthouses and national defense. *See* Lemley, *supra* note 219, at 995–96.

makes for a tidy metaphor, but it has little to do with information in the real world.

As Gregory Bateson has observed, "information" is "a difference that makes a difference."[225] Bateson's observation is illustrated by the old conundrum beloved by freshmen philosophy students: "If a tree falls in the forest, does it make a sound?" Physics tells us that the falling tree displaces air in waves regardless of whether those waves strike anyone's eardrums. But are those waves information? Until the waves produced by the falling tree are perceived, translated, and interpreted, they make no difference. Once they impinge on a living organism, however, the organism's behavior changes. The "difference" produced by the falling tree — sound waves versus no sound waves — makes a "difference" to the organism perceiving the sound waves, perhaps causing a state of heightened awareness or a flight reaction.

Prior to the perception-translation-interpretation process, waves are merely signals that have the *potential* to bear information. A complete definition of "information" requires content, perception, translation, and interpretation. In other words, information requires context.[226]

The observation that information requires context has been extended by industrial organization and innovation theorists into the concept of "communities of practice."[227] The communities of practice concept recognizes that knowledge does not exist in a vacuum, but rather is an interdependent part of an evolving system that also includes practice and technological artifacts.[228] Knowledge and innovation typically emerge from a long history of culture and skills acquired from within a community of practice.[229] Given this understanding of how knowledge is created, information cannot meaningfully be severed from the context in which it was generated.[230]

This context-dependent concept of information means that the traditional view of information as a nonrivalrous resource holds little practical value outside of some very narrow contexts. Perhaps information as merely platform-neutral computer code can be disembodied and decontextualized; however, biological code cannot. When one moves from ideas of disembodied information — whether one calls them Plato's forms, Jefferson's Natural Law, the laws of physics, or

225. GREGORY BATESON, STEPS TO AN ECOLOGY OF MIND 459 (1972).

226. *See id*.

227. *See* Ikka Tuomi, *Internet, Innovation, and Open Source Actors in the Network*, 6 FIRST MON. 1 (2001), *at* www.firstmonday.org/issues/issue6_1/index.html/tuomi/index.html.

228. *See id*. at 4.

229. *See id*. at 3.

230. *See id*. at 2.

cyberspace — to the regulation of the distribution and use of context-dependent information, it becomes clear that information possesses aspects of economic, social, and biological rivalry.

1. The Economic Dimensions of Information

The traditional model of the information commons overlooks how information is used in a competitive economy. As Michele Boldrin and David Levine have argued, perhaps unconsciously echoing Bateson's definition of information, "Only ideas embodied in people, machines, or goods have economic value."[231] Although an idea in the abstract can be shared by an infinite number of people without depleting the idea, an idea as embodied in a person, machine, or good cannot be reproduced without cost.[232] Even when the costs of reproduction are low and there are no intellectual property protections, the first mover has an opportunity to obtain rents.[233] If anything, Boldrin and Levine demonstrate that lower costs of reproduction make it easier for the first mover to cover its production costs and obtain rents.[234] Therefore, even absent intellectual property protection, the first-mover advantage makes information a rivalrous resource.

A second way that information can be rivalrous is when information has independent economic value. This is often the case with trade secrets. Thomas Jefferson recognized this in his often-quoted letter to Isaac McPherson: "If nature has made any one thing less susceptible than all others of exclusive property, it is the action of the thinking power called an idea, *which an individual may exclusively possess as long as he keeps it to himself*; but the moment it is divulged, it forces itself into the possession of everyone . . . ."[235]

This conception of secret information as a rivalrous resource is reflected in trade secrecy law. Most definitions of what constitutes a protectible trade secret include a requirement that the purported trade secret confer a "competitive advantage" on the holder that can be diminished through improper disclosure.[236] The competitive advantage conferred by trade secrets is the ability to obtain rents as the sole

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231. Michele Boldrin & David K. Levine, *Perfectly Competitive Innovation*, 303 FED. RES. BANK OF MINNEAPOLIS STAFF REP. 4–5 (2002).

232. *See id*. at 8.

233. *See id*. at 9–11.

234. *See id*. at 12–13.

235. Letter from Thomas Jefferson to Isaac McPherson, *supra* note 195, at 180 (emphasis added). J.H. Reichman and Paul Uhlir similarly recognize that information that is "bundled and embodied in physical artifacts" is therefore appropriable to some degree. Reichman & Uhlir, *supra* note 108, at 365.

236. *See, e.g.*, Robert G. Bone, *A New Look at Trade Secret Law: Doctrine in Search of a Justification*, 86 CAL. L. REV. 241, 248 (1998).

holder of the secret.[237] The value of true trade secret information would be diminished if the secret were disclosed.

2. The Social Dimensions of Information

Information can also become rivalrous through the value placed on the information by a social structure. Consider the example of religions or social organizations with secret teachings that are revealed only to a faithful few. In Mormonism, for example, adherents who have demonstrated sufficient loyalty can participate in "endowment" ceremonies at Mormon Temples.[238] The endowment is seen as "the temporal steppingstone through which all people must pass to achieve exaltation with God the Father and Jesus Christ."[239] As part of the ceremony, participants learn "names, signs, tokens, and penalties" that are to be kept secret.[240] Other examples of secret rituals, signs, or passwords in various cultural and religious settings abound.[241]

Secret information of this type typically has no economic value. Unlike a trade secret possessed by an inventor, this type of information does not provide a superior product, better method of production, or first-mover advantage in a market.[242] The secret information does, however, possess substantial social value. It helps maintain organizational cohesion, attract new adherents, and keep outsiders away.

Disclosure of this sort of secret information can diminish the information's value. If adherents realize the information is known by others outside the organization, they might experience less compulsion to follow the organization's norms or even to remain in the organization. Moreover, potential new adherents will have less incentive to join the organization. Therefore, in this sense, information also is a socially rivalrous resource.

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237. *See id.* at 262–63.

238. *See* David J. Buerger, *The Development of the Mormon Temple Endowment Ceremony*, 20 DIALOGUE: A J. OF MORMON THOUGHT 33 (1987).

239. *See* David J. Buerger, *"The Fulness of the Priesthood": The Second Anointing in Latter-day Saint Theology and Practice*, 16 DIALOGUE: A J. OF MORMON THOUGHT 10, 11 (1983).

240. *See* Buerger, *supra* note 238, at 34.

241. *See, e.g.*, MARK C. CARNES, SECRET RITUAL AND MANHOOD IN VICTORIAN AMERICA (1991); Paul Rich & David Merchant, *Religion, Policy, and Secrecy: The Latter Day Saints and Masons*, 31 THE POL'Y STUD. J. 669 (2003); Andrew Metz, *A Tie That Binds? Bush's, Kerry's Secret Society*, NEWSDAY, Oct. 18, 2004, at A23 (discussing the common membership of presidential candidates George W. Bush and John Kerry in Skull and Bones, a secret society at Yale University).

242. It could be argued that the secret information adds to the allure of the religion or social organization and thereby allows the organization to attract new converts. *See* Rich & Merchant, *supra* note 241, at 670. However, there is not competition between most religions and social organizations in an economic sense because the belief systems offered by "competing" organizations are typically not substitutable.

3. The Biological Dimensions of Information

The information commons has a biological dimension. Since biological code is transformative — it effects change within the receiving organism — information that is encoded in organisms has aspects of biological rivalry.[243] With its transformative nature, biological code can be a means of controlling and transforming an organism. The Enlightenment concept of a disembodied Natural Law is therefore inadequate for biological information. The law must be concerned with how people perceive, translate, and interpret potentially information-bearing signals.

This is particularly so if one seeks to break information down into layers of code that might or might not be open in an information commons. Consider a digital recording of Mozart's *Magic Flute* that is transmitted over the Internet. One can easily identify the traditional code layers in such a recording and transmission.[244] There is the written musical score from which the flutist originally played; the digital recording itself; the algorithm used to compress the digital recording for Internet transmission; any additional information that may have been added to the recording during compression, such as copy controls; the various layers that make up the Internet; and the object and source code of the software used to play the transmitted file.[245]

The layers of code, however, do not end there. As the file is played, the listener's computer speakers displace air, creating vibrations that travel through the atmosphere as sound waves.[246] This also is a layer of code. The sound waves strike a hearer's eardrums, which causes the small bones in the inner ear to vibrate,[247] sending an electrical signal down the auditory nerve to the hearer's brain.[248] This electrical signal is yet another layer of code. The electrical signal is translated by the hearer's brain into an astonishingly complex cascade of neurochemistry, which allows the hearer's consciousness to per-

243. Some activists echo this concept of biological rivalry when they argue against intellectual property rights in biotechnology development. *See, e.g.*, RIFKIN, *supra* note 91; FRANCIS FUKUYAMA, OUR POSTHUMAN FUTURE 84–92 (2002) (discussing concerns raised by the prospect of control over genetic information, in particular, eugenics).

244. *See supra* notes 3–9 and accompanying text.

245. *Cf.* Lawrence B. Solum & Minn Chung, *The Layers Principle: Internet Architecture and the Law*, 79 NOTRE DAME L. REV. 815, 944 (2004) (discussing code layers in copy controls, the Internet, and software); Brendan M. Schulman, Note, *The Song Heard 'Round the World: The Copyright Implications of MP3s and the Future of Digital Music*, 12 HARV. J.L. & TECH 589, 591 (1999) (discussing code layers for transmission of digital recordings).

246. *See* How Stuff Works, How Hearing Works: Sound Basics, *at* http://science.howstuffworks.com/hearing1.htm (last visited Nov. 29, 2004).

247. *See* How Stuff Works, How Hearing Works: Bone Amplifier, *at* http://science.howstuffworks.com/hearing4.htm (last visited Nov. 29, 2004).

248. *See* How Stuff Works, How Hearing Works: Fluid Wave, *at* http://science.howstuffworks.com/hearing5.htm (last visited Nov. 29, 2004).

ceive a sound.[249] This neurochemistry is at least one additional layer of code. Underlying all these layers is the DNA that instructs the organism's cells on how to build the physical structures through which this neurochemistry passes and by which it is translated into perception.[250]

From an information commons standpoint, there has never been much reason to be concerned over these biological code layers. Now, in the biotechnology era, there is. Control over biological code layers implies control over how any organism perceives, thinks, and behaves. Thus, standard information commons theory is inadequate as a metaphor for biotechnology. Biotechnology requires a model of the commons that incorporates the complexity of biologically encoded information. Indeed, although the information commons metaphor remains in wide use, scholars have begun to recognize its limited descriptive force, at least implicitly, by creating different variants of commons theory. Before reaching a firm conclusion about whether commons theory remains viable as to biotechnology, this Article addresses these variants.

D. Variants of Commons Theory in Intellectual Property Law

Because they view information as a non-rival resource, most information commons theorists see the privatization of information as a hindrance to efficient commons management. However, there has been a growing awareness that information in the real world is less of a unified commodity than traditional information commons theory suggests. Recently, intellectual property scholars have attempted to address this complexity by developing variants of traditional commons theory. Two such particularly relevant efforts to the biotechnology information commons are semicommons theory and anticommons theory. As discussed below, neither offers a sufficient description of, or solution to, the problem of access to biotechnology research and inventions.

1. Semicommons Theory

Henry Smith describes a hybrid of private and commons property, which he has dubbed a "semicommons."[251] Semicommons property is

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249. David P. Corey et. al, *TRPA1 is a Candidate for the Mechanosensitive Transduction Channel of Vertebrate Hair Cells*, NATURE (advanced online publication, Oct. 13, 2004), *at* http://www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/vaop/ncurrent/full/nature03066_fs.html&content_filetype=PDF.

250. *See supra* Part III.B.2.

251. Henry E. Smith, *Semicommon Property Rights and Scattering in the Open Fields*, 29 J. LEGAL STUD. 131 (2000).

a resource that is used in common for an important purpose, but otherwise is held privately. These private and common uses dynamically interact.[252] Smith provides the example of the medieval open-field system, in which a field was open to common grazing during certain seasons but divided into privately held segments during crop-growing season.[253] This interaction of public and private uses allowed the peasants to benefit from economies of scale for certain activities (e.g., grazing, manure spreading) yet still maintain small-scale private ownership for those activities that were better suited for private incentive systems (e.g., grain growing).[254] However, this system encouraged strategic behavior as individual users would attempt to divert the burden of common usage to parcels other than their own, for example, by directing the travel of animals over another's land parcel.[255] To combat this strategic behavior, the private parcels were allocated in narrow, intermixed strips to make diversion of burdens and resources more difficult, a practice Smith calls "scattering."[256]

Recently, Robert Heverly has suggested that semicommons theory applies to the information commons.[257] Proceeding from a definition of "information" as "any thing that has potential to be acted upon because of its content,"[258] Heverly discusses the dynamic interaction between the private and common aspects of information. He illustrates this interaction with several examples.[259] First, Heverly describes an author's use of publicly available, "common" facts about a public figure for the "private" use of creating a copyrighted biography.[260] Adding onto this example, he then describes how a book review might be written, making a "common" use of the "private" copyrighted contents of the book.[261]

In Heverly's view, efforts to distribute information having private characteristics without the private owner's consent (for example, file swapping of copyrighted music on peer-to-peer networks) and efforts to lock down the common components of information (for example, digital encryption of non-copyrighted portions of a digital work) are examples of strategic behavior that undercut the efficiencies of the semicommons.[262] Where common use of information at the distribu-

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252. *See id*. at 131.
253. *See id*. at 134–36.
254. *See id*. at 134–38.
255. *See id*. at 139–42.
256. *See id*. at 144–54.
257. *See* Robert A. Heverly, *The Information Semicommons*, 18 BERKELEY TECH. L.J. 1127 (2003).
258. *Id*. at 1150.
259. *See id*. at 1167–72.
260. *See id*.
261. *See id*.
262. *See id*. at 1172–83.

tion level does not impair the benefits of the information's private use, the common use should be permitted.[263] Thus, Heverly concludes, activities like file swapping should be permitted absent evidence that the activity is directly harming the potential actions the private user could take.[264]

It is unclear whether semicommons theory could apply to the biotechnology commons. First, semicommons theory itself is questionable. The "semicommons" described by Smith could as easily be characterized as a form of collective management of a common pool resource. By formal or informal contract, villagers agree to allocate farming parcels in the commons so that, both temporally and physically, the land could productively be used by all the villagers for both farming and grazing. This is analogous to the paradigmatic commons management technique described by Ostrom, by which Turkish fishers allocated the spacing of nets across productive fishing grounds.[265] The resource itself — the fishing grounds or open fields — remains a commons. The allocation of access to the commons simply reflects a collective agreement on commons management.

In addition, Heverly's definition of information, from which his concept of the information semicommons flows, is inadequate. Heverly views information as something with its own existence, in that it has "potential" even before it is perceived by anyone. As discussed in Part IV.A above, this reflects a modernist view of knowledge that in turn derives from the Enlightenment view of Natural Law. A more current philosophy of information, which is more consistent with the idea of information as potential property, views information as something that must be perceived by an organism.

Finally, Heverly seems to conflate synergies between *different* bits of information with a dynamic public/private interaction within a *single* bit of information. This results partially from the misconception of information as a sort of disembodied Platonic form.[266] Although the book review might incorporate some concepts and passages from the book for purposes of explanation and commentary, its primary purpose is commentary and analysis about the book. Therefore, the book and the book review are separate bits of information rather than different aspects of the same information. Once these different bits of information are disaggregated, the semicommons theory of information falls apart.

Semicommons theory, then, is helpful in that it recognizes how certain kinds of information do not fit neatly into preexisting com-

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263. *See id.* at 1183–88.
264. *See id.* at 1187–89.
265. OSTROM, *supra* note 212, at 144–46.
266. See *supra* Part IV.C for a further discussion about the meaning of "information."

mons models. However, it does not solve the biotechnology commons problem because it rests on an inadequate definition of information and fails to present any alternatives beyond classical collective management theory.

2. Anticommons Theory

The concept of an "anticommons" derives from Michael Heller's influential 1998 Harvard Law Review article.[267] As Heller explains, in anticommons property, "multiple owners are each endowed with the right to exclude others from a scarce resource, and no one has an effective privilege of use."[268] In anticommons property, there is no hierarchy of rights among these multiple owners and no mechanism for resolving disputes among them.[269]

Heller's paradigmatic example of anticommons property is the privatized storefronts in post-Communist Russia.[270] The privatization process occurred incrementally. As a result, different federal, local, and private entities simultaneously held portions of the property rights in the storefronts.[271] The right to sell or lease the property, for example, was separated from the right to receive sale proceeds or lease revenues, and these rights were further separated from the right to occupy the premises.[272] Because an individual merchant could not unify these rights into a useable bundle, the merchants chose to operate from street kiosks while the storefronts sat vacant.[273]

Heller notes that anticommons property need not necessarily be "tragic." The various rights holders could reach contractual agreements to use the property, or social norms might develop to compel collective decision-making.[274] However, where contractual arrangements imply significant transaction costs or where social norms favoring collective action are slow to develop, the resource is subject to tragic underuse.[275] Under these circumstances, Heller argues that it would be more efficient to privatize property by conveying the core bundle of rights to a single owner.[276]

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267. Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621 (1998).
268. *Id*. at 624.
269. *See id*. at 670.
270. *See id*. at 633–35.
271. *See id*. at 637–38.
272. *See id*.
273. *See id*. at 623.
274. *See id*. at 676–78.
275. *See id*. at 624, 676–77.
276. *See id*. at 688.

Heller and Rebecca Eisenberg have extended anticommons theory to biomedical research.[277] According to Heller and Eisenberg, an anticommons in biomedical research may arise by awarding multiple patents on fragments of future products or by allowing owners of upstream patents to obtain overly-broad license rights over the discoveries of downstream users.[278] Fragmented patent rights might include, for example, patents on research tools such as gene segments.[279] Overly broad downstream license rights might include reach-through licenses that allow the holder of a research tool patent to obtain ex post royalties on any profitable inventions developed using the research tool.[280] According to Heller and Eisenberg, private bargaining will not cure these anticommons effects because of the high transaction costs entailed in aggregating and valuing bundles of biotechnology patents, the heterogeneous interests of the rights holders (which often include both public and private entities), and the difficulty of predicting ex ante the potential value of future discoveries that may be facilitated by a given research tool.[281]

The threat of a biotechnology anticommons has captured the imagination of legal scholars and business theorists. Curiously, contrary to Heller's original thesis, many of the proposed solutions to this apparent problem, including that suggested by Heller and Eisenberg,[282] involve at least partial deprivatization of the patent asset. Janice Mueller, for example, has argued that the biotechnology anticommons problem could be solved by an expanded experimental use exception for research tools.[283] Similarly, Maureen O'Rourke has proposed the creation of a fair use doctrine in patent law that would permit infringement for the purpose of designing around a patent's claims.[284] Finally, Dan Burk and Mark Lemley recently proposed a hybrid deprivatization/privatization approach.[285] They suggest that courts should strictly interpret the obviousness requirement, so that fewer biotechnology inventions qualify for patent protection, but interpret the disclosure requirement liberally, so that the biotechnology

277. Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCI. 698 (1998).

278. *See id*. at 698–99.

279. *See id*. at 699.

280. *See id*. at 700.

281. *See id*. at 700–01.

282. *See* Heller & Eisenberg, *supra* note 277, at 701 (concluding that privatization must be carefully deployed and that restrictive licensing should be minimized).

283. *See* Janice M. Mueller, *No Dilettante Affair: Rethinking the Experimental Use Exception to Patent Infringement for Biomedical Research Tools*, 76 WASH. L. REV. 1, 66 (2001).

284. *See* Maureen A. O'Rourke, *Toward a Doctrine of Fair Use in Patent Law*, 100 COLUM. L. REV. 1177, 1237–38 (2000).

285. *See* Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575 (2003).

patents that do issue are broad and strong.[286] According to Burk and Lemley, this would limit the anticommons problem by thinning out the thicket of patents rights that would need to be negotiated by a later innovator, while preserving the incentive for innovation provided by the prospect of strong patent rights in a truly novel, non-obvious invention.[287]

Anticommons theory helps to highlight the difficulty some firms and researchers face in identifying and negotiating the rights needed to enter a commons. However, it is inadequate as a meta-narrative for several reasons. First, the description of biotechnology as an anticommons may simply be inaccurate. In Heller's original paradigmatic example of an anticommons, some of the key players were government officials who had permit authority over the use of newly-privatized storefronts. These officials had strong incentives to withhold permits in order to extract bribes; the greater the holdup potential of the office, the more individuals would be willing to bribe.[288] In contrast, the holder of a research tool patent ordinarily would want its patent to be licensed.[289] Only through dealing can the patent-holder make money.[290] Absent some other strategic consideration, there is little incentive for the holder of a research tool patent to refuse a license or to price the license out of the market.[291]

Also, the availability of patents might encourage strategic behavior with *positive* spillover effects for the public domain. In particular, firms might decide to disclose, rather than patent, some research tools in order to prevent rivals from winning a patent race.[292] This might particularly be the case when a large pharmaceutical company develops research tools that can be used by smaller biotechnology firms to discover treatments that might later be licensed or acquired by the larger firm.[293] Moreover, some patents might serve to spur innovation as competitors seek to invent around the patent.[294]

286. *See id*. at 1681–82.
287. *See id*. at 1682.
288. *See* Richard A. Epstein & Bruce N. Kuhlik, *Navigating the Anticommons for Pharmaceutical Patents: Steady the Course on Hatch-Waxman* (University of Chicago, John M. Olin Law & Economics Working Paper No. 209, 2004), at 4, *available at* http://www.law.uchicago.edu/Lawecon/WkngPprs_201-25/209.rae-bk.anticommons.pdf.
289. *See id*. at 5.
290. *See id*.
291. *See id*.
292. *See* Douglas Lichtman, et al., *Strategic Disclosure in the Patent System*, 53 VAND. L. REV. 2175 (2002); Gideon Parchomovsky, *Publish or Perish*, 98 MICH. L. REV. 926 (2000) (discussing strategic points in a patent race at which a party might choose to make public disclosures rather than to seek patent protection).
293. *See* Epstein & Kuhlik, *supra* note 288, at 8 (citing the example of Merck publishing express sequence tags it had discovered so that they could not be patented by others).
294. *See id*. at 6.

Finally, and perhaps most importantly, none of the anticommons literature correctly apprehends the quasi-rivalrous nature of information. The assumption that any information commons can be opened without depleting the information resource is unfounded.[295] In particular, none of the literature focuses on the sociology of biotechnology research or the vital role venture capital plays in biotechnology development.

It seems dubious, then, that open source should receive a favored place in biotechnology development policy. Open source may have its place in certain types of projects, such as the Human Genome Project, for which it may be optimal for scientists and research institutions to donate their efforts.[296] Those firms that choose disclosure as a strategy might choose to dedicate their research to the public domain by making it available on an open source basis. However, the economic structure and social norms of the biotechnology industry suggest that commons management through private rights and bargaining is a better baseline policy approach. Nonetheless, there are some objections to this approach. This Article discusses some of the more common ones in the next section.

V. COASE AND THE PENGUIN'S DNA

Thus far, the traditional information commons can be seen as a metaphor with little correspondence to reality. Information as a Platonic abstraction may be non-rivalrous, but true information is not an abstraction. Information is embodied in people and organisms and has aspects of rivalry in its economic, social, and even biological axes. A truly open information commons, therefore, is unlikely to exist. Indeed, the Mertonian (and Jeffersonian) vision of an open science community is weakened not only by intellectual property laws, but also by the personal, economic, and social forces that shape researchers and their institutions. For these reasons, an open source biotechnology model likely will do little to facilitate long term, significant innovation. Given these constraints, one might expect that private transactions would be an efficient means of allocating innovation resources in biotechnology, so long as the Coasian assumption of no transaction costs holds.[297] Yet, the perception remains that private rights are creating a logjam for innovation. In the next few sections, this Article will review the transaction costs and strategic behavior that might disrupt efficient bargaining over access to biotechnology rights.

295. *See supra* Part IV.C.

296. *See supra* note 83 and accompanying text.

297. *See* Ronald H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1 (1960).

A. Transaction Costs and the Innovation Game

Much of the concern over the enclosure of the biotechnology research commons assumes that transaction costs associated with licensing multiple patents will be prohibitive and that patentees will refuse to license an essential technology for strategic reasons. For example, as Rai and Eisenberg note, "The public domain economizes on transaction costs by eliminating the need to find and bargain with patent owners, allowing research to proceed expeditiously and without the risk of bargaining breakdown."[298] They believe a market-based response to the anticommons "depends on unrealistic assumptions about the information, foresight, and goals of people who are bargaining with current or potential scientific and commercial rivals."[299]

Rai has provided one of the most comprehensive analyses of why transaction costs complicate a Coasian approach in biotechnology licensing.[300] According to Rai, assigning broad intellectual property rights with private bargaining is a poor solution to the biotechnology commons problem because of the following transaction costs: the broad patent rights advocated by property rights theorists such as Edmund Kitch would impede parallel independent development;[301] valuation of a biotechnology patent license can be problematic, because much of the technology is relatively new and has unknown utility;[302] a prospective licensee will be loath to reveal unprotectable research plans, but may not be able to get a patent license without this disclosure (a variant of Arrow's information paradox);[303] and the highly iterative nature of biotechnology research means that a prospective licensee likely will need to clear multiple levels of rights relating to any given point in the development chain.[304]

There are good reasons to think that most of Rai's concerns, although real, should not foreclose a market-based solution to the biotechnology anticommons. Valuation seems the least problematic of Rai's concerns. It is a problem common to any innovation market, and is routinely addressed through the corrective effects of bargaining

298. Rai & Eisenberg, *supra* note 103, at 298.

299. *Id*. at 297.

300. *See* Rai, *supra* note 101, at 121–29.

301. *Id*. at 124. Rai was specifically addressing Edmund Kitch's prospect theory of patents. *See* Edmund W. Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265 (1977) (arguing that patents are analogous to mineral prospect rights in that their primary function is not to provide incentives for innovation, but rather to allow otherwise fallow resources to be efficiently allocated through licensing); *see also* Burk & Lemley, *supra* note 285, at 1683 (noting that prospect theory, at least in part, describes the role of patents in the biotechnology field).

302. *See* Rai, *supra* note 101, at 125.

303. *See id*. at 126.

304. *See id*. at 126–27.

between repeat players and disclosure of past bargaining results. A variety of approaches have been employed to value patent royalty rates in this kind of context. These include the cost method, which adds an arbitrary margin above the cost of creating the patented invention; the market method, which reviews historical data from comparable licensing transactions; and the income method, which is based on projections of net cash flows from the invention.[305] Recently, F. Russell Denton and Paul Heald proposed a modified version of the Black-Scholes equation (used to value stock futures contracts) that could be used to value patent licenses.[306] Regardless of the approach used, it seems clear that rational parties have the ability to negotiate a mutually acceptable license price and that open markets have the ability to correct improper price points.

The problem of parallel development also is not unique to biotechnology. Again, the same problem arises in any emerging technology market. However, in many cases where the payoffs are high, patents might *spur* parallel development by fostering patent races or encouraging incremental improvements.[307] Indeed, this is what often happens in traditional pharmaceutical development as well as in biotechnology development. Cancer research, for example, is funded through a web of public and private money.[308] The share of cancer research funding by traditional pharmaceutical firms and venture-funded biotechnology firms increased from 2% in 1974 to 31% in 1997, while the overall total amount of funding increased from $2.7 billion to $5.1 billion.[309] In short, if there is a viable market, there will be parallel development.[310]

The information paradox concern is also misplaced. Contrary to the understanding of many information commons theorists, the problem of Arrow's information paradox is *less* serious for patent-dependent industries such as biotechnology than it might be for copyright-dependent industries such as computer software.

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305. *See* F. Russell Denton & Paul J. Heald, *Random Walks, Non-Cooperative Games, and the Complex Mathematics of Patent Pricing*, 55 RUTGERS L. REV. 1175, 1183–90 (2003).

306. *See generally id*.

307. On the question of patent races, see *supra* Part IV.D.2.

308. *See* NAT'L CANCER POL'Y BD., REPORT ON SOURCES OF CANCER RESEARCH FUNDING IN THE UNITED STATES (1999), *at* http://www.iom.edu/Object.File/Master/12/783/0.pdf.

309. *Id*. at 17–18.

310. For a game theory analysis of when a firm will choose to innovate or imitate with respect to a drug in the international arena, see David W. Opderbeck, *Patents, Essential Materials, and the Innovation Game*, 58 VAND. L. REV. (forthcoming 2005) (manuscript on file with author). Where there is not a viable market — as in the case of orphan drugs — other incentives, such as those provided under the U.S. Orphan Drug Act, may be appropriate. *See id*.

As Mark Lemley has noted, someone who wishes to make an incremental improvement on a work protected by a proprietary right faces a dilemma: in order to obtain a license to improve the original work, the improvement must be disclosed to the prospective licensor; but if the improvement is disclosed, the licensor could refuse to grant the license and simply appropriate the improvement herself.[311] This is particularly troublesome under copyright law because the original author has control over the creation and distribution of derivative works.[312] In contrast, the limits on patent claims as well as the availability of "blocking patents" mean that patent law restricts the degree of control a patentee can exert over future improvements.[313] An improvement that is nonobvious in light of the prior art (including the patented invention upon which it improves) is itself patentable.[314] Although the improver cannot use the underlying invention without infringing the original patent, the original patent owner cannot appropriate the improvement without infringing the improver's patent.[315] The paradox is then solved; the improver can negotiate without fear of free riders.[316]

Even absent patent protection, the improver can protect herself contractually. Nondisclosure and noncompete agreements are commonly used at the evaluation stage of a licensing relationship, and more complex forms of materials transfer agreements frequently accompany research tool licenses.[317] Thus, the information paradox problem is not likely to serve as a significant hurdle to biotechnology transactions.

Finally, Rai's concern about the difficulty of identifying and coming to terms with prospective licensors is well taken. As Mark Lemley has observed, the time and resources that must be expended to find and negotiate with prospective licensors, as well as the risk of inadvertently overlooking someone who might hold proprietary rights, impose non-trivial costs on would-be innovators.[318] Searchable public databases, in particular government patent office databases, make this task somewhat easier. However, as noted in Part II above, patents are only one part of the amalgam of proprietary rights that might surround a biotechnology research program. Copyright claims are far more difficult to search because the public database is not user-friendly, the

311. *See* Lemley, *supra* note 219, at 1052 & n.289.
312. *See id*. at 1052 & n.290.
313. *See id*. at 1000–13.
314. *See id*. at 1008–09.
315. *See id*.
316. *See id*. at 1052.
317. *See* Rai, *supra* note 101, at 111.
318. *See* Lemley, *supra* note 219, at 998, 1053–54; *see also* Rai & Eisenberg, *supra* note 103, at 298 (noting that the public domain eliminates the need to "find" patent owners).

registration documents contain only minimal information, and there is no registry for claims based on DRM technology. Thus, search and bargaining transaction costs are a serious problem.

The problem, however, is not insurmountable. In fact, although it is one of the central issues in a market-based response to managing the biotechnology commons, it is one of the most straightforward to solve. There should be a central repository of all variety of proprietary claims over biotechnology inventions. Such a repository would not eliminate search costs altogether, but it could reduce them to the point that they become inconsequential. Part V.C below discusses this Article's conception of such a database.

B. Strategic Behavior

Transaction costs are not the only objection to the prospect patent model for biotechnology. A second objection to a Coasian approach to the biotechnology research commons is that strategic behavior may pervert the bargaining process.[319] As Rai and Eisenberg note, biotechnology licensing transactions often involve "bargaining with current or potential scientific and commercial rivals."[320] For example, a firm that has developed a research tool might refuse to license it to a competitor, and instead might license it exclusively to another firm that wishes to use the tool in developing a commercial product. A university that has compiled a database of proteins with certain properties might refuse to make it available to faculty at a rival institution.

There is little empirical evidence about such potentially problematic strategic behavior, but evidence suggests that a holder of upstream patent rights might also choose strategies that *benefit* exploitation of the invention. The paradigmatic case is the Cohen-Boyer patent for recombinant DNA, which is cited as the "most-successful patent in university licensing."[321] The technology was developed in universities through publicly funded research and was patented as permitted under the Bayh-Dole Act.[322] The technology is offered under a relatively low license fee and on generous terms; volume licensing has proven quite lucrative.[323] Thus, a very basic upstream technology — much like more traditional "tool" technologies such as Bunsen burners, pyrex tubes, and lasers — can be licensed at a substantial profit without unduly disrupting the research stream.

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319. *See* Rai & Eisenberg, *supra* note 103, at 297.
320. *Id*.
321. *Case Studies*, *in* NAT'L RES. COUNCIL, *supra* note 164, at 40.
322. *See id*. at 41.
323. *See id*.

The polymerase chain reaction ("PCR") technology, developed by Cetus Corporation and now owned by Hoffman-LaRoche, is another example of markets limiting the negative aspects of strategic behavior. Like the Cohen-Boyer technology, PCR is a fundamental research tool in molecular biology.[324] Roche offers the PCR technology through a tiered licensing system: for basic research purposes, PCR is available on very generous terms; for purposes more directly related to Roche's core business of human diagnostics, license fees increase sharply.[325] While some smaller companies that want to compete in the diagnostics business have complained about this licensing scheme, the generosity of its terms to the Human Genome Project was a key to the project's success.[326] The PCR case shows how the availability of patent protection can spur a traditional research-based pharmaceutical company to develop a tool for a particular commercial purpose and then offer licenses on more generous terms for other purposes.

Yet another case illustrates how patents can attract venture capital to seed innovation that simply would not otherwise have occurred. For example, the academic science community initially viewed automated protein sequencing instruments with skepticism.[327] The inventors of these machines were unable to obtain public funding or to publish their findings in prestige journals.[328] However, a large biotechnology company funded continued research, obtaining the patent rights to the technology.[329] That company, in turn, cross-licensed its technology with a small biotechnology company that had obtained patents on infrared fluorescence DNA sequencers.[330] Thus, patent rights made two important research tools available.[331]

Strategic behavior, then, is not a one-note song. The choice of strategies is not simply "release" or "withhold." Within a robust market structure, the holder of a proprietary right in a research tool is more likely to adopt a variegated strategy that will make the tool available on reasonable terms for most uses. In the next part, this Article presents a brief model of an exchange that could help reduce transaction costs and impede negative strategic behavior, thereby facilitating such licensing.

324. *Id*. at 43.
325. *See id*. at 44.
326. *See id*. at 43–44.
327. *See id*. at 46–47.
328. *See id*. at 47.
329. *See id*.
330. *See id*.
331. *See id*. at 48.

C. Toward a National Biotechnology Database

The analysis in Parts V.A and B above suggests that the principal issue in the biotechnology research commons is access to data that will help reduce transaction costs and strategic behavior. Therefore, biotechnology innovation policy should focus not on weakening intellectual property rights or on encouraging alternative development methods such as open source, but rather on making such data available. Judge Easterbrook has laid out three criteria for facilitating exchange in virtual communities: rules, property rights, and a "bargaining institution" through which exchange can occur.[332] Of these, the first two already exist. This Section briefly outlines a "National Biotechnology Database" ("NBTD") that would help eliminate transaction costs and facilitate a robust market for biotechnology intellectual property licensing.

The basic concept of the NBTD is simple: bring together all the information that prospective licensees and licensors need to enter into efficient transactions. This requires at least the following: (1) a clear description of the technology, (2) a list of any claimed intellectual property rights in the technology, (3) price information, and (4) information about license terms. Some of this information already exists in public intellectual property registries, such as those maintained by the U.S. Patent and Copyright Offices. However, there is no central source of price and term information. In addition, much relevant information is not registered anywhere, such as data that is not patented or data that is copyrighted and locked up with DRM technology. Step one, then, would be to establish the central database.

Reichman and Uhlir recognize the importance of a centralized, or at least federated, repository of research data.[333] Their vision, however, essentially is of an open source data center, in which government-sponsored research data is unconditionally available and private research data is available under something akin to the Creative Commons license.[334] This suggestion is helpful, but incomplete. There is no indication that existing norms of information-sharing in private biotechnology development will change to facilitate this model. Moreover, as discussed in Part III.B.5 above, the existing norms derive from the venture-financed nature of the industry, without which much innovative work would not happen.

My proposed model forces transparency of the licensing market to lower transaction costs in a closer approximation of the Coasian

332. *See* Frank H. Easterbrook, *Cyberspace and the Law of the Horse*, 1996 U. CHI. LEGAL F. 207, 210–13.
333. *See* Reichman & Uhlir, *supra* note 108, at 426–31.
334. *See id*.

ideal. In the NBTD, firms (or individuals) that choose to participate would be required to make complete and accurate disclosures, but the transaction price would not be set by any external authority. The NBTD would not impose an open commons from the outside in. A rights holder could choose to refuse to license its technology. Yet even holdouts would be required to participate in the database by providing information about their technology. The duty to participate would be triggered by public disclosure, such as a patent application or publication of data under a claim of copyright or with DRM controls. This duty would be consistent with existing disclosure duties under patent law.

The NBTD would significantly reduce transaction costs. Prospective users of listed technologies would only need to consult one source for the data needed to make licensing decisions. License transactions would conclude more rapidly. Also, with complete information about available substitutes and full disclosure of license terms and prices, competition would exert downward pressure on the prices for many research tools and other basic technologies. The NBTD could thus provide a map with which prospective licensees could better navigate the maze of intellectual property rights in biotechnology.

The NBTD also would help curtail strategic behavior. By requiring disclosure of license price and terms — or of a refusal to license altogether — the NBTD would facilitate market pressure against holdouts. In cases of strategic behavior that is collusive or that severely distorts the market, antitrust regulations might play a role.[335]

Finally, the NBTD might have spillover benefits in the form of new markets and financing devices relating to listed technologies. Venture capitalists, for example, should find it easier to value intellectual property assets traded on a central market. Finance devices, such as futures contracts tied to the market price of intellectual property licenses, could be developed. Bundles of related rights could more easily be aggregated in patent pools and licensed together at lower rates.

The NBTD, however, would not be a perfect solution. Some technologies are so unique that the lack of available substitutes will limit the market's ability to impact license prices or terms. Moreover, it will not always be easy to identify the proper scope of any proprietary rights in a given technology or the terms on which it should be licensed. However, as the industry matures, these problems should begin to fade for at least commonly repeated transactions, such as those for licensing. In this way, the market should achieve the goal of

335. *See, e.g.*, U.S. DEP'T OF JUSTICE & FED. TRADE COMM'N, ANTITRUST GUIDELINES FOR THE LICENSING OF INTELLECTUAL PROPERTY (1995) (discussing strategic licensing practices that could run afoul of antitrust law).

open source proponents: a robust research and development environment in which researchers have access to the tools they need so that both private and public biotechnology science can progress.

VI. CONCLUSION

Open source offers an interesting alternative to government control or private bargaining over rights to a commons. Open source production, however, will not occur on any significant scale absent certain conditions. Certain types of software have been developed effectively through open source methods because the projects were divisible and granular, the roots of the necessary social structure existed in early "hacker" communities, and copyright license models were adaptable to support open source norms.

Biotechnology, however, is different. The information commons rhetoric of open source software and the Internet fails to withstand scrutiny when applied to biologically-based technologies because "information" can no longer be defined as an independent entity that can be possessed equally by infinite users. Instead, "information" is context-dependent. This is particularly true of biologically-encoded information, which effects direct change in an organism. Under a context-dependent definition, there are economic, social, and biological aspects of rivalry connected to an information resource. A truly open information commons therefore is an unobtainable myth.

Because information is in some sense rivalrous, there must be some method of allocation. Collective management by way of open source development is appealing, but biotechnology lacks the sort of community that would make it feasible. In particular, the classical and neo-classical story of science as a homogenous, cooperative enterprise that is being corrupted by private property rights does not correspond to reality. Science, and in particular biotechnology, was, and will be, rife with competition and gamesmanship.

Given these circumstances, a Coasian approach suggests that private property rights should lead to bargaining that will, over time, efficiently allocate the information resources. Many of the transaction costs identified as barriers to such bargaining should not pose insurmountable problems, particularly as players repeatedly interact over the same or similar resources. The most problematic transaction costs are the search costs entailed in defining and clearing multiple rights held by diverse parties under differing intellectual property regimes.

If search costs are a primary barrier to bargaining, the primary aim of biotechnology innovation policy should be to reduce those costs. One way this could be accomplished is to establish a national technology database containing information about proprietary claims, license terms, and license prices. Although this solution would not be perfect, it represents a means of reducing barriers to biotechnology innovation consistent with existing norms.